A Global Knowledge Building Design Experiment: Saving the Planet, Saving Lives

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To Know or not to Know chess: Epistemic agency in a kindergarten classroom as a moral and ethical domain

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Abstract: In this paper we highlight epistemic agency as distributed and ultimately a moral and ethical domain consequential for our relations with one another and for knowledge building community norms. We highlight how social interaction is a rich site of study where ethical and moral ideas are made explicit. We interlace the narrative with commentary on how epistemic agency in interaction is distributed, negotiated and related to the domain of ethics and morality. Our micro-ethnographic analysis of a short video where three children co-construct a chess game reveals that for the children, to know or not to know chess is not the question. Rather, knowledge and agency in interaction is dynamic, graded and emergent in the collusion of participants where knowing how to be with each other and why is as important a question as the know-how of chess.

Introduction

In this paper, we utilize interaction analysis to frame epistemic agency as distributed and a product of the emerging collusion of participants in learning interactions. The analysis takes a microethnographic approach of children's interactions with each other and their teachers in a kindergarten classroom. It proceeds from the dictum: 'Ab uno disce omnes: From one thing, everything can be said – and must be said.' (McDermott and Raley, 2011, p. 375) Paying attention to kindergartners' gestures, postures and conversation, *the fleeting world built together in interaction is analyzed* – with particular reference to the tacit accomplishment of action, revealing the silent ground of what is emerged. To listen to the silence is not to say 'there is no science but of the hidden,' rather it is an articulation of 'horizontal distributions, combinations between systems of possibilities … to try to reconstruct the conceptual framework that makes it possible to conceive of a statement.' (Ranciere, 2013, p. 46) We are here concerned with the analysis of the first principle of Knowledge Building Communities: Epistemic Agency. (Scardamalia, 2002) We analyze a 2-minute interaction of three children playing chess and present it in narrative form. The recording was taken as part of ethnographic observation that spanned 12 weeks with 30 hours of observation. In the spirit of Knowledge Building, we merge analysis with the design of comic book narratives that foreground the bodies, gestures and conversation of children engaged in ethical and moral arguments while bringing alive a chess game. We are concerned here with local interactions being consequential for learning how to be with each other. (McDermott, 1977) This analysis is in tune with work that seeks to de-centralise and diffuse epistemic agency and responsibility and considers its relational aspects. (Hinchman, 2018)

The etymology of the word 'agency' could be traced to the Latin 'agere': to set in motion or drive forward. (Etymonline, n.d.) In Biblical terms, it can be traced to the Greek egeneto: to come into being. Panta di autou egeneto: All things through him came into Being. (Deeks, 1976) To look for a more lateral location of agency, we look for the term as it has been conceptualized in the analysis of social interaction.

There are various frames for articulating agency that lead us down different paths. Here we speak of it as fundamentally distributed and consequential for ethical or moral ends. Kockelman highlights an Aristotelian lens: the four causes an agent can be held accountable for: 1) the material cause or *qualis*. (How is something constituted? What is it's nature?); 2) the formal cause (What is the underlying genesis and patterning of this cause?); 3) the final cause (What are the functions such a formed substance serves?); and 4) the efficient cause (What are the ends of the cause?) (Kockelman, 2017, p. 15) This frame highlights the world as open to inquiry and play – a world that has been shaped by the activity that preceded it.

Kockelman (2017) juxtaposes an Aristotelian account of agency with that of Bacon, thus depicting the coupling of knowledge and power. 'If knowledge turns on the discovery of causes, power turns on the directing of causes.' (p. 16) Thus, for us as analysts, giving an account of epistemic agency in kindergartners playing chess is as much an account of us formulating agency for specific means and ends. Goodwin (1994) describes how seeing is a deeply situated activity tied to the community of practice that makes sense of phenomenon. Within scientific communities, practices of coding, highlighting and producing graphic representations are used to make sense of interactions. Elaborating on how the minute video analysis of the beating of Rodney King by four police officers was used to gain an acquittal by the defendants in a courtroom, Goodwin describes how the event was reframed in terms of 'rational' professional discourse. Fitted into categories, particular aspects of images were figured in relation to the complex visual field to demonstrate their account of what happened. (p. 608) Alexander (1994) asks the question: Can you be Black and look at this? She states that '"the evidence of things not seen" is crucial to understanding what African American spectators bring to the all-too-visible texts at hand.' (p. 81) Thus, Alexander and Goodwin alert us to the issues of power at stake in the depiction of demonstrations that elaborate gestures, bodies and conversation of people in interaction through categories of the disciplines we are speaking to and from. The theories and learning we articulate need to be continually attuned to how they might blind us. (Varenne and McDermott, 1998, p. 20)

Thus, in our presentation of 'what happened,' we make the use of the form of fictional narration to represent a microstrip of interaction. This form is conducive to polyvocality (Bakhtin, 1935) and attunes us to the sensuous mode of lived interaction and ethnographic description. (McDermott, 2015) Further, it allows for a metaphorical or vertical form of telling that is radically reflexive. 'What is constructed through the art of artifices should artfully display its artificiality.' (Trin and Kobayashi, 2005, p. 171; as cited in Gallagher, 2008, p. 111) On yet another level, we propose a design activity where young children and their teachers can fill in their own narratives and accounts of the moral conundrums of embodied interaction and reflect on their conversation of gestures. For the purposes of this paper, we use *ethics* in the sense of *the kind of person one should be and how one should live*, while *morality*, as part of ethics, deals with questions of *'what one should do next'* and the 'obligations, prohibitions, general principles, systematicity and momentary decisions' that guide interaction. (Keane, 2017, p. 20) If ethnography is the search for the right questions, the one we grapple with in this paper is: How might we foreground the ethical and moral considerations of children in naturally occurring activity as objects to reflect on and learn from.

The narrative

The sea heaved mightily, pregnant with child, as a storm engulfed the boat trying to dance with the wave. Prospero, a giant of five-years sat to my right. You want to play chess? A joust? A fibble – won't take long. Beat you last time didn't I? Played with my father – you think I can be a champion?

Analysis: Mathematical and scientific literacies, when embedded in activities children are familiar with from informal environments, are particularly conducive to building bridges between formal and informal environments: they are rich grounds for fostering agentive behavior, practice-linked identities (I want to be a chess player) and islands of expertise. (Hull and Greeno, 2006; Nasir, 2009; Crowley et al., 2002) Moreover, the kinds of activities they afford can be fertile areas for developing school-based literacies. Indeed, Hull and Greeno (2006) argue schools should be a space to foster learning in informal environments, rather than vice-versa. Agency in one sense can be seen as distributed using the example of a mother-child dyad: an infant looks at an object and points at it, while the mother brings it closer for the child to interact with. However, this explains how the interaction is shaped this way rather than why. (Raczaszek-Leonardi, 2017, p. 161) (Rogoff, 1990)

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In the bridge, the helm, lay a table with its chess pieces ready to battle. Heave, heave, boatswains, cried Miranda majestically. Ferdinand, his hair tawny and disheveled stood over the table, grimly surveying the troops there assembled – looked warily at Miranda marshalling the boat and then back at the table – his thick lashes curtaining the water well, engrossed in his interior monologue. I got there, disbalanced, steadying my camera as Prospero took to the seat waiting for him. He rested his elbow on the table, his fingers curled into a fist as he sunk his cheek into it. My scribe duties took the best of me. Ferdinand plays chess for the first time, write I. Prospero likes to play the game with his father. He beat me twice. I won thrice – smugly, set I the camera and by the time I was ready with my eye-piece, the game had begun – Miranda had taken the third seat – two chess pieces lying before her. Ferdinand stood, as if ready to leave at any moment – a guest. His hoodie meticulously zipped up three-quarters of the way; a lightning bolt adorned it – and just then, a bolt embellished the sky behind, roving its way to the horizon of the ocean as the thunder greeted their meeting. The storm has engulfed them all and they have to play their way through it. The spirit Ariel, that Miranda wields, featly makes her way to the boatswains; her song metes them to their slumber.

Analysis: Agency *Who and what here is agentic?* The age-old game is played through time and the world over. The pieces on the board have affordances that can be revealed only according to certain rules; a knight goes two forward and one right; the castle vertically or horizontally can take those in its way. Miranda holds two pieces from off the table as she engages in make-believe – the Knight is now Jack and the Queen is Jane; they pass each other by, and Jane stops; facing him. Is the spirit Ariel who wielded Miranda's command to slumber agentic? The chess pieces? Are the ones on the table and off it agentic in the same way? And what are they agentic for?

Returning to the framing of agency as the four Aristotelian causes and the Baconian extension of knowledge as the search for these causes coupled with the power of directing them, Kockelman (2017) highlights the recursive, reflexive and relative nature of agency. As Prospero may have learnt as he developed his chess expertise, it is recursive in so far as the discovery of new causes: rules of chess, strategies etc. yield the discovery of yet further causes, and the power to do new things with them. As such, the agent can characterize and thematize such knowledge and their actions can be held accountable for such things as praise, reward etc. Agency is relative, i.e. it has 'potentially heterogeneous suites of context-specific and ever-contingent causal capacities.' (p. 17) Prospero's knight faced with a castle and a queen can offer him possibilities different than when a bishop stands ready to break his stride. Indeed, off the table, Miranda can make them to be Jack and Jill meeting in a park.

To respond to the *question of whether Prospero is agentic in the same way as the chess pieces*, Kockelman makes a distinction between *instrumental agents* and *derivative agents*. Restricting Aristotle's framing to set aside material and formal causes, and focusing on efficient and final ones, the question becomes one of means utilized to achieve ends. Agents then, can be considered more or less agentive based on the possibilities of means at their disposal to achieve a suite of ends. Prospero having played chess on a variety of occasions trumps Ferdinand who has the same number of pieces but knows not what each can do – yet, Ferdinand has his utterances, gestures, body, imagination, ratiocination, instrumentality etc. to work towards the end of forging through the storm. They are, in Kockelman's terms, lively agents, infused with mentality. The knight on the board, while instrumental – it can move two and a half to pursue the end of taking over another piece – is derivative rather than originary for it cannot take purposeful action. Ferdinand, Miranda and Prospero are auto-telic for they have themselves as ends and auto-technic, for they have themselves as means. They enclose the endless search for causes – towards a final end. Aristotle, writes Kockelman, called such an end eudaimonia: human flourishing or happiness. (p. 19) Here, braving the storm is a possible end for this chess game – or other values held by this community. As people who can be held accountable for their agency, it begs the question: what moral and ethical frameworks the trio attend to in assessing routes to take in interaction? Hence, the final end that encloses the search for causes is the question of how to be with one another and towards what ends: domains of moral and ethical thought. This end could be articulated as relations of trustiness (McDermott, 1977), we-ness (Vossoughi et al, 2020), ethics of reciprocal care (Noddings, 2012), or collective responsibility (Scardamalia, 2002).

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Four moves have been made, as I see Ferdinand unsure of whether it is his turn to act. He moves his hand over the table, hovering over it. As he reaches to grab a pawn, Prospero extends his own to intercept it, gently taking ahold of it as Ferdinand retreats his. The Goddess Dignity pricks him as he sucks in his upper lip cheekily embarrassed. It was not his turn.

<u>Analysis: Episteme in Interaction</u> Speaking about the differential distribution of knowledge in participants, Stivers et al. (2011) write about how interactants attend to issues of epistemic access. Ferdinand in extending his hand to make a move, presupposes, claims and elicits access to the normatively organized social distribution of knowledge. The normative here, as we have mentioned earlier are the rules and strategies coalesced around the game. Being but his first time playing, Ferdinand gains access to the rule of turn-taking by eliciting Prospero's interjection through making a wrong move.

This interaction that keeps alive the game despite its unequal epistemic distribution is not devoid of emotions and morality. Emotions are best theorized as socially constructed. (Campbell, 1994; Boler, 1999) Following George Mead, we can state that the self and the other arise in the social act together. (Mead, 1909, p. 169; as cited in McDermott and Varenne, 1998, p. 5) Here, dignity can be seen to be distributed. Prospero in gently taking hold of Ferdinand's hand displays to the analyst that he is the kind of person who treats others with dignity for it reflects who he himself wants to be seen as. (Keane, 2017, p. 110) Ferdinand and Prospero having gained congruence in epistemic access, and dignity only slightly disturbed in the affair, the players can then continue with the co-construction of the game.

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Miranda takes hold of Jack and Jane who now have a bishop to play with as she spans the chess board with her gaze. Prospero uncurls his fist, his giant face sinking into the open hand, ears strutting out. Ferdinand straightens his head as his hand turns in his pockets – in the waiting is the task of strategizing and posturing. Miranda leans forward to whisper through the air as Ariel sweeps through Prospero's chest, who brings his right hand across the table, takes hold of the castle, and runs through the board six spaces with it and displaces the pawn there settled. Ferdinand takes his pocketed hand out as he says, *No!* Prospero, twisting his trunk takes hold of Ferdinand's castle and vanquishes his own, placing his fallen piece gallantly in front of Ferdinand, as Miranda looks intently. Ferdinand though, unaware that his turn too has been made, fixates on Prospero's initial movement of the castle, complaining *he hadn't taken his piece that far!* I could do it - Prospero tells him.

<u>Analysis: Epistemic primacy and responsibility</u> Stivers et al. (2011, p. 17) further describe how interactants manage issues of social structural alignment and affective affiliation through epistemic primacy and responsibility. Epistemic primacy relates to the asymmetries in interaction that prevail over relative rights to knowledge and relative knowledge. This kind of primacy can be derived through social categories (teacher, parent etc.) or through local interaction roles, for example, who has access to a state of affairs. Epistemic responsibility on the other hand, relates to the responsibilities people have towards knowledge. For example, people hold each other responsible for what is in the common ground. Here, Ferdinand appeals to his right to know that Prospero is infringing on his rights. He has access to the prior knowledge of his own turn, where he 'didn't know the castle could go as far.' He tries to hold Prospero

accountable to what he knows so far about the game. Prospero, on the other hand, uses his role as someone who has played chess more often to assert that he could move seven squares with his castle. This discrepancy needs to be negotiated. Stivers et al. (2011) argue that the issue of managing knowledge in social interaction is always a moral affair.

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Miranda steadies the boat with her left hand, heaving her chest as she pushes to gain respite from the ocean as it swells and dwells. Prospero is back in his thinking stance as Ferdinand brings forth his hand only to be caught by Prospero's: 'My turn,' says he. Dignity again plays her charms, as he sulks. Miranda twists her torso, offering an open-hand as she tells him he already had his turn. Prospero too, extends his hand pointing to the castle, as Ferdinand gets distracted by a fallen piece. Prospero waits while Ferdinand recomposes himself and points to the move he had done on his behalf. Congruence in epistemic access regained, it is soon Ferdinand's turn – who reaches forward, drives the pawn one space ahead – receives no complain from Prospero, and smiles smugly. He then points to a bishop with his finger pointing at hypothetical places it could go and receives confirmation from Prospero slightly guiding his hand.

Analysis: Knowledge and morality Thus, we see in these snippets that in social interaction, it is not simply whether the two players know chess or not. Rather, it is an affair of bargaining and calibration to arrive at a mutual understanding of the norm-governed situation. Interactants 'attend not only to who knows what, but also who has a right to know what, who knows more about what, and who is responsible for knowing what.' (Stivers et al, 2011, p. 18) Thus, knowledge and morality are intricately linked, and are consequential for the management of social relationships. From Kockelman's (2017) formulation we saw that agency has as an ultimate goal - a moral or ethical end.

'I can play chess' is not juxtaposed with 'I can't play chess.' At the local emergence of their play, the fact that Prospero is a budding chess player, while it is Ferdinand's first time playing doesn't seem to hold much import. The trio are ensuring smooth progress of the game and are involved as much in cognitive strategizing as they are in ensuring rights and obligations, managing the construction of turns and engaging in repair activity – negotiating, calibrating and bargaining each turn to engage with the norm governed genre of the chess game. The forms matter as a negotiated frame, where attention is paid to whose claims at what particular point in time are entertained. Knowledge, write Stivers et al., in interaction is 'dynamic, graded and multidimensional' and 'these micro-interactional moral calibrations have critical consequences for our social relations.' (2011, p. 3) Keane (2017, p. 153) argues that social interaction is a rich site to observe and comment on ethical stances that people negotiate as they engage in ongoing activity and it provides crucial elements in the production of morality systems. It is there that ethical concepts are made explicit and can be used as objects of discussion to reflect on ethical and moral questions. Thus, rather than offering a specific set of moral or ethical ends, we propose comic book narratives that describe situations where learners encounter moral negotiations, to coalesce discourse on ethics around them. (Figure 1) The design draws on de Jorio's study of Neapolitan gestures that created stories around tableaus of people interacting with each other. (Kendon, 2004, p. 47)

Figure

Figure 1: Prospero, Ferdinand and Miranda negotiate turns

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Miranda raises her hands and whispers: one-two-one; put on my thumbs; one-two-one; coins like crumbs. Ariel swoops down and there appears a guinea each on her extended thumbs. Ferdinand, at this moment simulating with his hands, the moves that he would make to blow holes through Prospero's firmaments, looks to his right and declares: He that will be champion shall win these guineas. With renewed vigor, he lifts up a pawn but lets it go. None shall it conquer, so why make this move – at which point Portia, the teacher who had been observing from afar entered with an unseasonable question: Have you played this game of chess before Ferdinand? For much does rest on your industriousness – the storm engulfs us and makes our insides twirl. Come, I'll show how you can set us at our ease. The pawn she points at, and Ferdinand looks on, can move one up and one down – he looks at her eyes and nods – but it's a tricky game, for at the beginning it can move two spaces. Miranda whispers again – and Ariel brings an inscription of the secrets of the game to aid with the instruction. But Portia continues: the castles are like the pawn but move all the way on. Ferdinand nods confused and Portia turns to Miranda: You've played this game before. Why don't you help Ferdinand? But Ferdinand sets up to leave. That's alright. I win, says Prospero, for I have more pieces. Yes, says Portia, but if for Ferdinand it was the first time playing, the game was a bit unfair. Portia sets to leave as the boat and the storm settles. Wait, says Miranda, let's not forget what to do before we begin. Prospero extends his hand and shakes hers. Yes, says Portia. It's an honorable game.

Analysis: Ethical trails in pedgagogic interactions: Let us analyze the pedagogical interaction between Portia and Ferdinand through the lens of Kockelman's (2017) dimensions of distributed agency. The rules, as to how each chess piece would move are constitutive of Aristotle's final cause. They provide the means that would endow the agent with the power to achieve particular ends.

As soon as Portia says it is a tricky game, Miranda presents her a diagram of the chess board with its pieces to aid her talk. Inscriptions and graphic representations become key objects within scientific communities to aid discourse and to represent work. (Goodwin, 1994, p. 611) When Portia sees that Ferdinand is not following, she asks Miranda to guide him through his turns. This would provide more context specific guidance within the give and take of the game. Discussion of appropriate ends did come up. Prospero boasted of having won, while Portia corrected him that being an honorable game, it was unfair to play for winning if one were playing with someone who had never played before. Miranda insisted they shake hands before playing in the spirit of cooperation.

Vossoughi et al. (2020) show how micro interactions contain ethical trails that learners carry and reproduce in future interactions. The snippets of interaction we have seen were suffused with ethical considerations – some implicit and others explicit. One does not goad over another's defeat; one shakes hands at the beginning of a game. However, how might these considerations that are usually explicit in teacher learner interactions, be brought to the fore and reflected over in peer interactions within naturally occurring activity where expertise is likely to be distributed? In this paper, we have offered comic book narratives to bring to fore embodied interactions from children's play and learning activities as points of departure for ethical reflection.

Conclusion

In this paper, we were interested in the *tacit accomplishment* of a trio colluding to construct a chess game in a kindergarten classroom. One of the players was playing for the first time, while the other was a budding chess player. To collude literally means 'to play together', from the Latin col-ludere. (McDermott and Tylbor, 1995, p. 278) Our analysis of the microstrip of interaction revealed that for the children to know or not to know chess was not the question they attended to. Rather, they were involved in bargaining, negotiation and calibration of epistemic responsibility and access to the normative domain of the rule-governed chess game. The fleeting world they built together was primarily attentive to smooth functioning of the chess game and their relations with one another. We proposed a design of comic book style narratives to coalesce dialogue around ethical and moral questions. Finally, we highlighted how epistemic agency was ultimately a question of what kind of people we want to be and how we want to relate to one another, which is consequential to the building of knowledge building community norms.

Note: The names and the theme for the narrative have been taken from Shakespeare's 'The Tempest' (2001).

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Transmedia sensemaking: Exploring youth's epistemic resources for knowledge building communities

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Introduction

> *… something is happening outside the school: social and technological changes have reframed the meaning of lifelong (over time) and life-wide (across locations) learning (Sefton-Green, 2003; 2006; 2013), and the emergence of new participatory practices (Jenkins et al., 2006; Lange; Ito, 2010) has redefined the ways of learning and even the actual concept of 'media literacy'. In this context the idea of 'transmedia literacy' proposes a move from traditional media literacy –understood as teaching critical media skills at school (Potter, 2004; 2005)- to the analysis of practices of participatory cultures, youth-generated contents and informal learning strategies ...* From Scolari, Masanet, Guerrero-Pico, & Establés, 2018, pp. 802-803

As underscored by Scolari and his colleagues in the quote above, something important is happening in the ways that youth are engaging in contemporary global media ecologies, calling for a deeper understanding of youth-generated content, informal learning strategies, and practices cultivated within these new participatory cultures. My inquiry centers on how youth make sense of phenomena and construct explanations using a variety of cultural artifacts drawn from across multiple platforms and forms of media (e.g., news stories, YouTube clips, films, storybooks), what may be thought of as "transmedia sensemaking." To illustrate the concept, I draw from a case study of the media-based practices of a young boy over the course of several months. I am interested in how the epistemic practices and stances made visible in the case study relate to the types of capacities that are important for participating in knowledge building communities (KBC's), and whether youth may be developing resources in out-of-school spaces that may be useful in cultivating classroom KBC's.

Theoretical Framework

Much of the knowledge building literature is grounded in the context of "a changing world" --- an expanding knowledge society --- where governments are calling for educational systems to change in order to support knowledge creation (e.g., Bereiter & Scardamalia, 2014; Scardamalia, 2002). Another framing, particularly in knowledge building classrooms focused on science learning, has been to investigate ways to create classroom communities of inquiry that mirror disciplinary communities (e.g., Bereiter & Scardamalia, 2012; Chuy, et al., 2011). The knowledge building work associated with both of these framings (my own work included) starts from the premise that what is happening in schools does not match what is happening in the wider *adult* society. There is also a growing literature in education and the learning sciences highlighting that what is happening in schools does not match what is happening in the wider *youth* culture (e.g., Ito, et al., 2020; Jenkins, et al., 2006; Luke, 2003). In the present paper, I want to move the lens to out-of-classroom spaces to better understand how youth are engaging in rich media landscapes, and explore what we might learn about the repertoires of practice (Gutierrez & Rogoff, 2003) and capacities that youth are developing in relation to knowledge building. The intent is to more deeply understand youth assets and funds of knowledge (Moll et al., 1992), what some refer to as "digital funds of knowledge" (Marsh et al., 2005), observed in youth-driven contexts, in order to think about how we might build from youth approaches in creating knowledge building communities.

With regard to what is happening in the wider youth culture, Marsh and her colleagues (2005) highlight "Young children are immersed in practices relating to popular culture, media and new technologies from birth. They are growing up in a digital world and develop a wide range of skills, knowledge and understanding of this world…" Research focused on youth in the "new media age" (Kress, 2003) points to changes in the nature of youth communication, play, and meaning making, and examines how youth develop of new types of identities, literacies navigational capacities, and social competencies. For example, "If we take remix in this broad sense – as processes of re-assembling, recontextualizing, and creating new meanings – then we begin to see remix practices not only on YouTube, fan fiction sites, or at the DJ table, but as an important part of young people's everyday media lives" (Burwell, 2014).

In the present paper I focus on transmedia engagement. Much of the transmedia research literature focuses on transmedia in entertainment contexts, particularly *transmedia storytelling* (Herr-Stephenson, et al., 2013). I am interested in emergent transmedia collections pulled together into cohesive forms by youth themselves, rather than engineered experiences created by children's media industries. It is possible that these two types may be linked, as youth who are well-socialized into navigating transmedia experiences engineered by children's media industries may be developing a fluency in working across media forms to make meaning. The youth involved in the case study was experienced with popular transmedia experiences, which may have influenced how he used multiple platforms and forms of media for sensemaking.

Context and Methodology

The case study centers on the transmedia sensemaking practices of a young boy, Ronin (pseudonym), over 19 months from ages 9-11. Ronin and I have known each other since he participated in an after-school arts club run by myself and a colleague for local 2nd graders. We re-connected at a neighborhood art event 2 years later, where I learned about Ronin's passion for storytelling. I invited Ronin to work with me to co-design a storytelling workshop for elementary-age children. Typically, we meet 1.5 hours/week at either the university or in his family's living room. Both the university and Ronin's home are located in a Northeast urban neighborhood, rich with ethnic, linguistic, and cultural diversity among US- and foreign-born youth.

I would describe our meetings as engaging in a sort of "story makerspace," where we come together to explore different genres of storytelling. I am positioned as a collaborator, but I mostly let Ronin determine the course of our work, with him choosing story lines and suggesting genres. Across the 19 months, we have explored storytelling through creating our own stop-motion movies, comic books, puppet shows, and other story forms. Over the course of our collaboration, I have been struck by the ways Ronin works across multiple media forms to make sense of phenomena and to construct explanations. In order to begin to more fully understand what I saw as "transmedia sensemaking," I used the audios, computer-screen shots, and field notes across sessions to locate illustrative examples of such sensemaking.

Exploring Transmedia Sensemaking

In looking across the sessions, a typology of transmedia sensemaking instances has started to emerge. Some of the instances arose as part of our storytelling, some came out of unrelated conversations as we worked together. Below I provide a brief overview of a few transmedia sensemaking types drawn from this initial analysis, namely:

- connecting representations of a concept over time,
- in-world inquiry into math and science problems, and
- co-constructing the meaning of a concept.

Connecting Representations of a Concept Over Time

The meaning making and connections in this example occurred over several sessions, with Ronin raising issues concerning feminist perspectives which he framed in relation to a variety of cultural artifacts. These connections began as we were working on our first story about two friends who are separated then reunited. Ronin underscored the importance of not being like the "typical story" where a prince saves a princess. He told me how, in the animated film *Moana*, the main character saves herself, and that the *The Princess and the Frog* has a very independent princess. He suggested that one of our stories should have a boy in distress and a girl saves him. Another day Ronin shared Pixar's *PIRL* on YouTube, where he drew attention to how the relationships between boys and girls "switched." When I asked Ronin what *PIRL* was about, he replied, "Sexism. Because there's 'B.R.O. Capital' and then a girl came." Over our months together, Ronin often stated the need for our stories to reflect strong women, which he punctuated with references to Mabel from the *Gravity Falls* cartoon series or showing me a YouTube clip of satirical Disney Princess songs (Jon Cozart's *After Ever After*) or other relevant YouTube clips.

Ronin drew on Disney princess movies, related YouTube clips, along with movie shorts and TV series as part of constructing a set of concepts related to feminism. Using these cultural artifacts as material for his ideas, Ronin compared contrasting cases and pulled together evidence for his claims. Over time, he identified connections across popular media artifacts and artifacts he found in the online space of YouTube, and pieced together various representations of gender relations and positioning in the artifacts to construct knowledge.

In-World Inquiry into Math and Science Problems

This instance arose with Ronin sharing an interest that he has been developing over time.

Ronin: Do you know for some reason I like, I like these theories. Do you know videogames and, like, movies? They do a bunch of theories on them, there's so much math.

Author: What do you mean "math"?

Ronin: Like, science and all that, like a bunch of research. Just for, like, videogames and stuff. (Laughs)

Author: So, what's the, give me an example. Like what kind of math?

Ronin: Umm. Like do you know Mario the, like, Tennis Game? …They're seeing if it is actually possible for a tennis ball to break a tennis racquet. And they did it. And it's super dangerous if that actually happened. …And if it was, everyone would die. …So, the ball would move too fast that the air molecules can't move out the way fast enough so there's gonna be explosions. Same scenario with Sonic [the Hedgehog], he runs too fast. …If that happened in real life, there'd be explosions everywhere.

In order for me to better understand the reference, we went to *The Game Theorists* channel on YouTube to watch *Game Theory: How to BREAK Mario*! In the clip, the narrator, MatPat, de-constructs the *Mario Tennis Aces* videogame, analysing in-game tennis phenomena through scaling, frame rates, and pixel measurements. The clip is full of sophisticated formulas and computations, which MatPat both deftly and humorously explains through referencing a variety of cultural artifacts (e.g., Sesame Street, real-life TV tennis matches, the Periodic Table) and comparisons to real-life measurement tools. When the clip presented varying computations depending on the type of metal in the racquet, Ronin joked, "He forgot one metal, Vibranium…the strongest metal ever" (a reference to the *Black Panther* movie).

In the particular clip that Ronin and I watched, MatPat positions the *Mario Tennis Aces* videogame as a model for scientific reasoning. MatPat begins the clip by establishing through step-by-step calculations how the videogame world and the actions within it are "pretty darn close to real life." MatPat then shows how this veracity permits him to make the claim that the force with which Mario would need to hit the ball to break an opponent's racket would be impossible: "Nothing short of a particle accelerator could make matter move that fast." This shares a similarity to Holbert and Wilensky's (2019) work on "videogames as objects-to-think-with." Although the Mario game is not built by educational designers as a microworld like the videogames used by Holbert and Wilensky, MatPat achieves some of the same objectives with a commercial game, including a "focus on the construction of knowledge, on creatively probing problems and experimenting with solutions" (p. 37).

The clip engaged Ronin, and scaffolded him in connecting in-world inquiry with the game to problem-solving methods and tools. Although some of the mathematical formulas were quite advanced, Ronin had watched the clip numerous times, and followed the reasoning and ways in which math and science could be drawn upon to support investigations. Ronin also seemed to understand the mapping of the in-world game features to real life phenomena, providing a way to model interactions and to identify and reason with variables. Ronin's own suggestions for considering what would happen with a racket made of a strong metal like Vibranium, or how the phenomena related to Sonic the HedgeHog (both fictional referents), showed him joining in the reasoning process in valid ways, both scientifically relevant and in keeping with the YouTube channel's approach of drawing from popular media-based worlds to play with ideas and propose hypotheticals.

One of the things that struck me was Ronin's expressed interest in theories and how they can be used as part of working through problems. In fact, two of his favorite channels on YouTube are *The Game Theorists* and *The Film Theorists*, both run by MatPat, an American Internet personality. Both channels have video clips where MatPat focuses on a specific cultural artifact from film or video games, begins with a problem or hypothesis, and works through a series of strategic moves, such as making claims and supporting them with evidence, using analogies, applying mathematical formulas or scientific principles. MatPat weaves together an explanation that satisfies the problem all while incorporating humor, silly but related tangents, and connections to a wide range of popular cultural artifacts. Over the course of our time together, Ronin often made reference to ideas from these two channels. Ronin appeared to find these theories engaging and enjoyed the puzzle-like nature of the problems that MatPat generated and worked through. Sometimes, Ronin would find the relevant clip on YouTube and use it to supplement something he was explaining to me, providing an opportunity for us to look together at a clip and generate our own new questions and elaborations.

Co-constructing the Meaning of a Concept

About 8 months into our sessions, Ronin and I worked together to build a shared understanding of "eminent domain." It began with Ronin sharing something he had learned about the main character in the Disney film *Wreck-It Ralph*: "He [Ralph] was minding his own, if you wait until the very end of the credits, they give you song. It's about eminent domain… It's horrible. It happens to a bunch of real people." We were both familiar with the concept, but did not understand it deeply. Ronin directed me to use Wikipedia, and we read the definition together. He also asked me to find a YouTube channel where he had seen a piece on eminent domain in Wreck-It Ralph that he had found helpful. During the course of our joint exploration, we also downloaded the Pixar film *Up* to see if eminent domain was behind Mr. Fredricksen's loss of property.

Ronin appeared to bring this issue up in our conversation because he had become curious about the paradox of a story character who is portrayed as "bad," but has a secret that unlocks meaning underlying his actions, showing that Wreck-It Ralph may not be what an audience has been led to believe. This seemed to be an interesting problem that moved Ronin to dig deeper and, drawing upon various media, he recognized complexity within the good/bad binary of film characters, placing a character's problematic actions in relation to contexts that felt unfair. Ronin's interest also led the two of us to search the Internet both for information (the Wikipedia definition) and additional cultural artifacts that might provide deeper insights into a new concept that had been introduced, "eminent domain." We both contributed cultural artifacts to the effort, and worked together from these various media forms to co-construct a shared understanding of the meaning of eminent domain.

Discussion

Dyson (1997), in a study of children's use of superheroes in classroom literacy activities, noted "A number of researchers have documented the tendency of young boys in particular in our society --- whatever their social class or ethnic background --- to appropriate material from popular culture for their oral and written stories" (p. 215). In current times, the Internet and access to a vast media landscape have expanded greatly the ways in which youth are able to share and manipulate material based on such cultural artifacts. Kalantzis and Cope (2012) contrast contemporary learners, who they refer to as "Generation P" (where the P stands for "participatory") to "an earlier generation of learners may have been more used to being passive watchers of stories at the cinema or on television; this was intrinsic to the producer–to–consumer dynamic in the 'mass media'" (p. 9). In today's Internet-supported participatory cultures, youth are able to connect with collectives engaging with popular culture through various media forms and in various ways, including online communal spaces devoted to CosPlay, fanfiction, and YouTuber's posting video-based artifacts deconstructing and playing with the ideas of films and videogames (Ito, et al., 2020; Jenkins, et al., 2006). Even though Ronin is not participating directly in the participatory culture of YouTube by generating and contributing his own artifacts, he can be seen as a peripheral participant in the online space. He immerses himself in this collaboratively-constructed dynamic media space, navigating across and interacting with a range of artifacts and channels, and developing a large catalog of resources to draw from. Offline, Ronin does generate explanations using the artifacts. He also orally discusses and elaborates on these artifacts with his peers (and collaborators like me), co-constructing in ways that can lead to further understanding.

Through following his interests in popular media, Ronin is learning how to navigate and build associations between knowledge objects across shared social spaces mediated by digital technology, what Jenkins (2010) refers to as *transmedia navigation*, "the capacity to seek out, evaluate, and integrate information conveyed across multiple media." Jenkins writes about the power of such activity, where "students need to actively seek out content through a hunting and gathering process which leads them across multiple media platforms. Students have to decide whether what they find belongs to the same story and world as other elements." Through navigating the various spaces, Ronin works across multiple forms of knowledge, analysing meaning and constructing an understanding of how the forms connect with one another. Reilly (2009) describes how working in this way opens up opportunities for youth to:

> … learn by searching and gathering clusters of information as they move seamlessly between their physical and virtual spaces. Knowledge is acquired through multiple new tools and processes as kids accrue information that is visual, aural, musical, interactive, abstract, and concrete and then remix it into their own storehouse of knowledge. (p. 9)

Further, Ronin's actions in the three examples of transmedia sensemaking indicate that he is developing various epistemic practices and capacities. These include making connections across knowledge objects, pulling together evidence for claims, considering different perspectives, and developing a feel for the use of theories in problem solving. Hakkarainen (2009) points out that "rather than arising from mysterious personal gifts or creative talents, innovation in discovery rely on collectively cultivated epistemic practices that guide and channel the participants' intellectual efforts in creative and expansive ways" (p. 215). Through immersing himself in the analytic approaches carried out on YouTube channels such as *The Game Theorists* and *The Film Theorists,* Ronin is becoming socialized into working with various media forms as knowledge objects, including identifying sub-texts of films, problem-finding and theory-building, and employing explanation-building strategies that incorporate math, science, and modeling.

The epistemic practices and capacities that Ronin is developing can be seen as assets or resources that may be useful in cultivating classroom KBC's. When we think about the types of capacities that are important for knowledge builders to have, Bereiter and Scardamalia (2016) point to the ability to make strategic knowledge building moves related to problem definition, idea development, idea improvement, and meta-discourse. While the capacities that Ronin is developing are not directed specifically toward advancing the frontiers of collective knowledge nor explicitly understood by him to be knowledge creating discourse moves, Ronin does appear to be building a repertoire of strategic moves for constructing knowledge and advancing understanding. Further, in the third transmedia sensemaking example, our two-person effort to co-construct an explanation for "eminent domain" relates to the types of knowledge building moves found in "multi-player epistemic games" (Bielaczyc & Ow, 2014). Although Ronin may be engaged in simplified forms of theory-building and social knowledge construction, they do provide a foundation on which to build.

In addition, Ronin is coming to understand and function in spaces that support the social exchange of knowledge, which is also important in cultivating classroom KBC's and working in knowledge building environments such as Knowledge Forum (Scardamalia, 2004). Bielaczyc & Collins (2006) discuss how the free exchange of knowledge objects in a public space accessible to all members of a collective is a key characteristic of knowledge creating communities. The knowledge objects in the shared space become "our ideas," available to be worked on by members of the community. Hakkarainen (2009) underscores the importance of the "'material agency' (Pickering, 1995) provided by the learning environment," (p. 219), where knowledge-centered practices are mediated by collaborative, epistemic technologies that permit participants to transform ideas "into digital entities that can be further articulated, shared, interlinked, and extended in long-term processes" (p. 215). The particular sub-space of YouTube that Ronin works within can be seen to have similar characteristics, with the communal space involving at least two types of knowledge objects: *cultural artifacts* (CA's) and *analytical cultural artifacts* (ACA's). The CA's consist of popular media creations such as films and videogames, re-playable media-based "worlds" with multiple features, texts, and sub-texts (e.g., the Pixar short, *PIRL*). The ACA's are re-playable media-based analyses of specific CA's, typically employing problem-solving strategies and reasoning, and often drawing from other CA's and academic knowledges to support the analysis (e.g., parodies of Disney princess movies that ask "what happens after *happily ever after…*?," *The Game Theorists'* analysis of the Mario game described above). The communal space sometimes includes meta-level analytic artifacts providing commentary on or syntheses involving the ACA's. Ronin seemed quite comfortable operating across these various levels, watching films; searching for, drawing from, and elaborating on the ideas found in the ACA's; and also examining higher-level analyses of the ACA's (e.g., commentaries, news concerning YouTube channels or the film and game companies themselves).

Overall, my goal has been to explore whether the epistemic practices and capacities that Ronin is developing might provide insights into the resources that contemporary youth may have available for creating classroom KBC's. The parallels between KBC practices and spaces, and Ronin's developing epistemic practices and engagement in spaces that support the social exchange of knowledge, suggest that Ronin may be building a useful foundation to work from in joining a classroom that functions as a knowledge building community. It is also important to ask if Ronin's case suggests ways to expand our thinking around creating knowledge building communities with youth. One aspect to highlight is that the types of analytic artifacts that Ronin learns from seem to more valued in the participatory culture he is engaged with when they are clever and humorous, in addition to being insightful. Although I do not elaborate on this issue here, it does seem important to explore further the humor and playfulness with ideas involved in the knowledge objects constructed in this particular sub-space of YouTube, the role this plays in motivating Ronin's participation in this work, and the implications of humor and play in knowledge building. It is also critical to expand the work beyond a single case study in order to develop a broader sense of the ways that youth are engaging in contemporary media landscapes, and to study classroom implementations that incorporate and build from youth resources.

Conclusion

In moving the investigative lens to out-of-classroom spaces to focus on a single youth this paper attempts to deepen our understanding of the ways in which contemporary youth are engaging in rich media landscapes, and explore what we might learn about their developing repertoires of practice (Gutierrez & Rogoff, 2003) and capacities in relation to knowledge building. The hope is that by better understanding the powerful forms of sensemaking that occur in youth-driven contexts (their "endogenous modes" of inquiry (Kiefert & Stevens, 2019)), that designers and teachers working to create classroom KBC's will be better positioned to be more inclusive of and build from youth approaches.

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Crisscrossing Information Spaces with the IdeaMagnets Tool

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Abstract: Situated in the tradition of Knowledge Building, this study presents the design of IdeaMagnets, a new tool designed bridge Knowledge Forum, a popular knowledge-building environment, with the open web through web annotation. With the IdeaMagnets tool, we conducted a four-week classroom intervention in five science class in an urban high school in the United States. By constructing a qualitative case study, we investigated how students connected public discourse on the *Green New Deal* and their classroom discourse about energy. Findings suggested that with IdeaMagnets students developed a culture of engaging with public sources to advance their knowledge goals. They were mindful of personal, small-group, and collective knowledge goals when annotating public sources, and they incorporated web annotations made by members of the class when improving ideas in Knowledge Forum. The IdeaMagnets tool design and its emphasis on openness have strong implications for the design of future knowledge-building environments.

Introduction

To what extent can we engage youths in building knowledge relevant to public discourse on vital issues such as sustainability and climate change? To what extent can we bring knowledge practices essential for knowledge creation to students' everyday engagement with public discourse? This paper introduces a design research project named *IdeaMagnets* that attempts to explore these two questions. During this project, we designed a technological tool, IdeaMagnets, to connect public discourse on the open web with science inquiry in the classroom. In this paper, we report a case study describing a classroom intervention conducted in five secondary science classes where students studied a science unit on Energy within the context of the *Green New Deal* in the United States. Below, we first review relevant literature grounding the IdeaMagnets project. After introducing the project, we then describe the project's first classroom intervention, report main findings, and discuss implications for future work in related areas.

Background

The IdeaMagnets project builds on Knowledge Building (KB), a community-centric educational approach initiated by Scardamalia and Bereiter (2006). As an integrated system of theory, pedagogy, and technology, KB aims to "refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture" (Scardamalia & Bereiter, 2006, p. 97). Central to KB as an educational approach is its intention to align schools with knowledge-creating organizations (Bereiter & Scardamalia, 2014). With support from technological tools, especially Knowledge Forum (KF), KB involves students to work collectively as a knowledge community to solve authentic problems by continually improving their own ideas (Scardamalia, 2002). More than three decades of research has demonstrated KB's efficacy in promoting domain understanding, multiliteracies, and epistemic fluency (Chen & Hong, 2016).

To facilitate authentic knowledge-creating practices, technological designs for KB need to support three key areas: (a) Empower learners to take greater collective responsibility in knowledge advancement; (b) Enable ideas to have trajectories of growth independent of human minds; and (c) Facilitate key epistemic practices among learners, such as evidence-based reasoning and metacognitive dialogues (Chen & Hong, 2016). Recent advances in the community reflect efforts made in these areas. For instance, the Idea Thread Mapper tool engages students in collective reflection on their KB discourse so they can co-organize their journey of idea improvement (Zhang et al., 2018). The Promising Ideas tool asks students to take the responsibility of finding "promising" ideas in their community so that they could invest limited resources in promising directions (Chen, Scardamalia, & Bereiter, 2015). To assess students' epistemic agency and shared responsibility, new analytic tools are created and applied to KB discourse data (Ma et al., 2016; Oshima et al. 2012).

However, current KB environments tend to operate as "walled gardens." To deeply integrate education into societal knowledge production, KB can seek to forge a deeper connection between classroom discourse with the public sphere. On a societal level, youths are already making contributions to dialogues about issues such as climate justice. Educators need to find ways to engage school learning with these societal issues so that the society can learn from youth voices and also position youths as creators of solutions to existential problems. Recent paradigms of learning have demonstrated the promise of harnessing connectedness to nurture youth participation (Ito et al., 2013; Taylor & Hall, 2013). To realize KB's vision of aligning classroom learning with knowledge creation, new designs are needed to tap into new modes of connectedness, participation, and expression. Thus, we propose a high-level conjecture (Sandoval, 2014): *By bringing essential KB practices (e.g., theory building discourse) to youth engagement with public discourse we can make knowledge building more pervasive and achievable among youths.*

The IdeaMagnets project

To test the high-level conjecture, the IdeaMagnets project attempts to extend KB discourse carried out in Knowledge Forum (KF) into broader cyberspaces by incorporating web annotation technologies. This project, contextualized within high school science, is motivated by the fact that youths make frequent use of web and social media content. To support idea development in KF, and across the web, the IdeaMagnets project attempts to create a knowledge infrastructure that couples a private KF space with the open web space. Ideas are "pulled" from various web spaces to form larger knowledge structures to give birth to newer and bigger ideas; hence the metaphor of "idea magnets." By doing so, IdeaMagnets advances toward the design intention of integrating classroom discourse with public discourse.

To achieve the design goal, the project adopted design-based research (Collins, Joseph, & Bielaczyc, 2004) and participatory design (DiSalvo, Yip, Bonsignore, & DiSalvo, 2017) as the guiding approaches. Year 1 of the project centered on iterative cycles of design workshops and software development in which teachers, researchers, and engineers teamed up to refine the technology. The central focus in this phase was to embody high-level conjectures in tools (Sandoval, 2014). In particular, we aimed to bridge Hypothes.is—an open-source web annotation tool—with KF so that students could easily capture ideas on the web and then import ideas into their KF discourse. Work in Year 1 yielded an IdeaMagnets tool design that included two key components:

(1) *A collaborative web annotation system based on Hypothes.is.* Using a custom setup of Hypothes.is, a student can annotate any public web document with reflective texts, add tags, and contribute annotations to their private/protected community (see Figure 1).

(2) *IdeaMagnets as a new KF feature that queries and imports Hypothes.is annotations.* While Hypothes.is supports threaded discussions, KF provides unique affordances for continual idea development. By adding IdeaMagnets as a new tool in KF, students can have direct access to their community's annotations within KF; they can index, filter, and search web annotations directly in KF. They can also directly drag an annotation into KF to create a *magnet-note* with its unique icon (see Figure 2).

In Year 2 of the IdeaMagnets project, we co-designed a classroom intervention with one high school science teacher and piloted the tool in five science classes taught by this teacher. The study reported in this paper aimed to understand how students used IdeaMagnets when bridging classroom discourse in KF and public discourse on the broader web. The following research questions were posed to guide the study:

1. In what ways did the use of web annotation facilitate students' sense-making of public discourse?
2. In what ways did the use of IdeaMagnets encourage students to connect public discourse with their classroom discourse?

Methods

Context and participants

The research context was an urban public high school in the midwest United States. With the designed IdeaMagnets tool, we conducted a four-week classroom intervention in five ninth grade science classes taught by a same teacher (n = 97; numbers of participating students in these classes were 14, 16, 22, 25, 20).

Prior to adopting IdeaMagnets, this science teacher had been using KF in his teaching for more than five years. Participating students (in their first high-school year) had been exposed to KB and KF for two quarters. However, it was the first time for the teacher and his students to use Hypothes.is and IdeaMagnets. To develop sufficient technical knowledge of Hypothes.is, students were asked to add Hypothes.is onto the browser and were engaged in a few in-class annotation activities such as annotating their school website. By the time of this study, students had developed some technical knowledge about using Hypothes.is to annotate the web.

Pedagogical design

During the study, the classes were working on a curriculum unit about energy and energy sources. With the "Green New Deal" (GND) trending in the news, the science teacher situated students' work within public discourse around GND. Following the KB pedagogy, students were asked to identify *authentic problems* GND alludes to and develop their *real ideas* to address these problems. To meet the curriculum objectives, students were asked to complete an energy project to demonstrate their understanding of energy, the carbon cycle, and climate change.

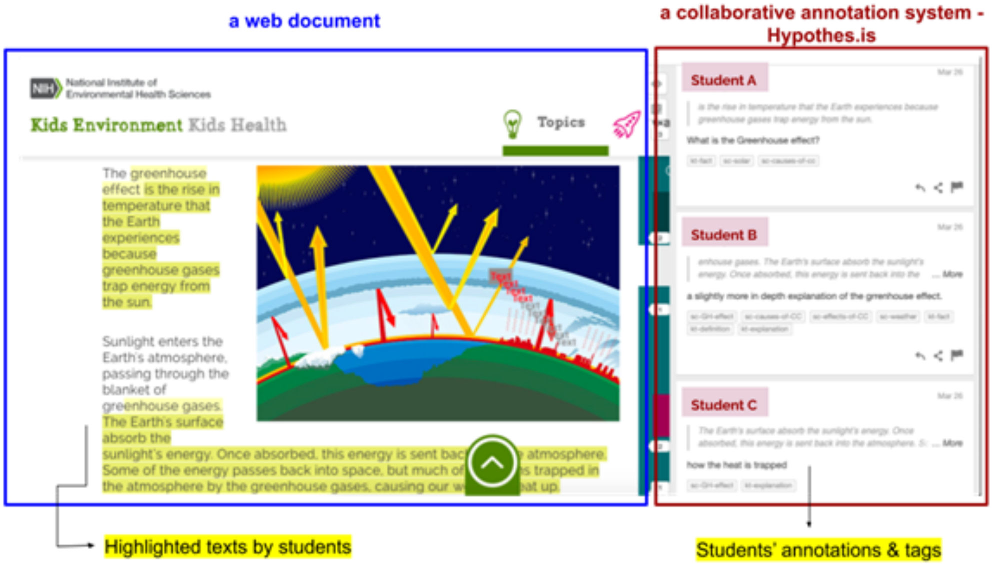

Figure 1. A collaborative web annotation system based on Hypothes.is. A student can highlight a piece of text in a web document (*left*) and create an annotation (and a conversation) about the highlighted text *(right*).

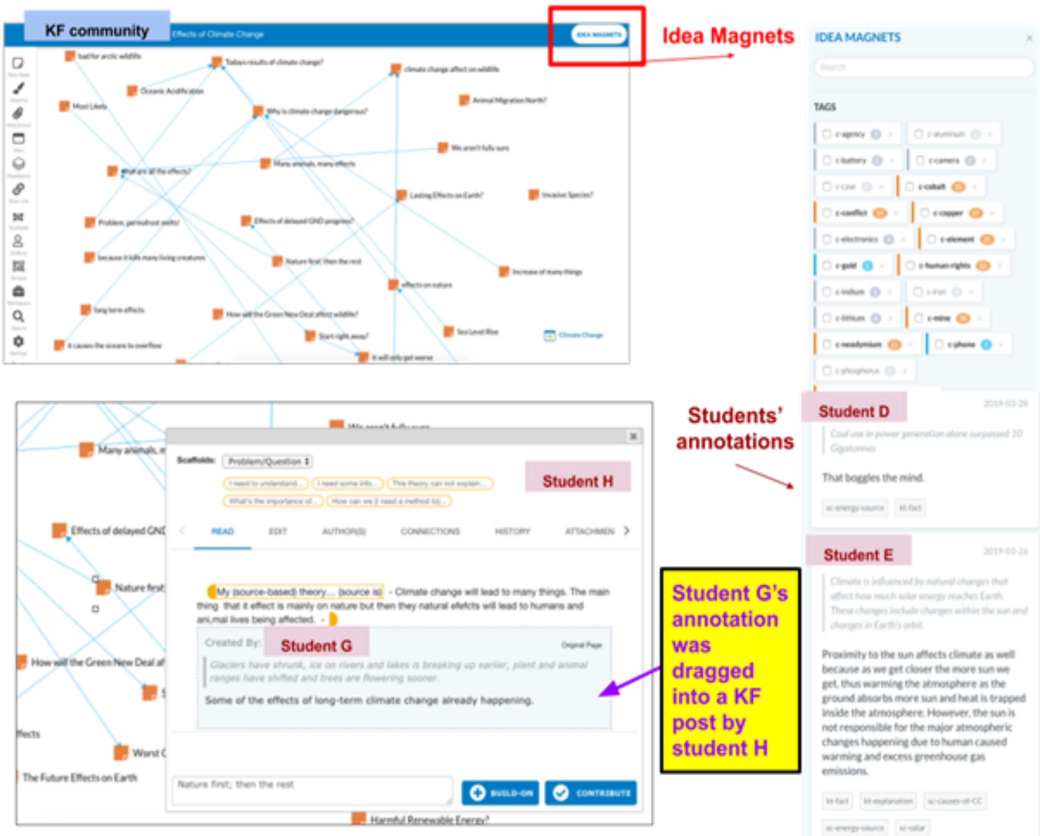

Figure 2. In a Knowledge Forum (KF) view (*upper-left*), Hypothes.is annotations from the community are aggregated in the IdeaMagnets sidebar (*right*), where students can filter annotations by tags or search (*upper-right*). An annotation of interest can be dragged into a KF note for further discussion (*lower-left*).

The teacher-researcher team came up with a pedagogical design emphasizing four KB principles (Scardamalia, 2002): (a) Community knowledge—the class as a community developed collective knowledge about problems related to GND, and they developed a system to index and use their community knowledge; (b) Improvable ideas—the class identified research problems within groups, crafted research questions in KF, and generated new ideas and improved them based on evidence; (c) Constructive uses of public sources—students used Hypothes.is to annotate and tag relevant articles on the open web to help them address knowledge problems; and (d) Knowledge building discourse—students had ongoing discussions across multiple weeks, such as using Talkwall (Smørdal & Rasmussen, 2019) in class to identify research problems, collectively defining tags for information seeking, using IdeaMagnets to pull ideas from web annotations, and deepening group discussion on KF. Detailed classroom activities designed to support these principles are presented in Table 1. The researchers collaborated with the teacher to identify public materials for students to read. The science teacher had students discuss the purpose of making annotations and invited students to discuss ways to improve their use of tags. By doing so, he gradually established a classroom norm in which students could use Hypothes.is to create annotations with meaningful tags. They generated two types of tags—*knowledge type* tags (e.g., fact, example) and *science concept* tags (e.g., "energy," "agriculture")—to index community ideas about climate change.

Table 1: An overview of the classroom activities in this study.

Weeks	Goals	Activities	Digital learning environments
Week 1	Collectively generate research problems	Read news articles about the GND, defined tags that mapped onto research problems	Twitter (searching tags), Google Form (collecting questions), Talkwall (organizing problems, questions, and tags)
Week 2	Form interest groups and formalize group problems	Formed three project groups: (1) Causes of Climate Change, (2) Goal of 100% Renewable Energy, (3) Effects of Climate Change	Knowledge Forum (posting group questions)
Week 3	Problem-centered engagement with public sources	Read and annotated additional web articles with proper tags.	Hypothes.is (annotating and tagging)
Week 4	Engage in evidentiary reasoning using web annotations	Continued to improve community ideas based on evidence introduced via web annotations	IdeaMagnets (filtering annotations), Knowledge Forum (improving ideas)

Data collection and analysis

To investigate how students engaged with public discourse on the web and how they built knowledge on KF, we relied on semi-structured group interviews with students as the primary data source and used fieldnotes and system logs as two secondary data sources. Based on student logs in digital systems (i.e., KF and Hypothes.is), we purposefully sampled two groups of students to share retrospective accounts of their learning experiences during this study. The first group (n = 15) included students who had actively used all three tools (KF, Hypothes.is, and IdeaMagnets) during the study. The other group (n = 15) included students who used these tools less actively. For each group interview, we pulled a group of three students from class and talked with them for 10-15 minutes about their reflection on their experiences. All the interviews were transcribed anonymously. We also drew on system logs to generate descriptive statistics of user behaviors and triangulate findings across all data sources.

The researcher conducted content analysis through two coding cycles: process coding and pattern coding (Saldaña, 2016). Each coding cycle generated researcher memos and open codes that captured learners' perspectives on why and how KF, Hypothes.is, and IdeaMagnets supported their learning (see Table 2). All the opening codes and memos were processed through axial coding through which the researcher merged related codes to form common themes.

Results

Table 2 shows results of the content analysis and provide an overview of how students actually used Hypothes.is and IdeaMagnets to approach public discourse, according to their responses. Overall, we found that in addition to technical features, they also mentioned various knowledge building affordances offered by these tools. Based on the coding results, Figure 3 further illustrates patterns of learners' sense-making processes as they connect public and classroom discourses. In this section, we first examine students' actual use of Hypothes.is and IdeaMagnets and then present patterns of their discourse processes.

In what ways did web annotation facilitate student sense-making of public discourse?

Actual usage and perceived usefulness of web annotation

During the Energy unit, 57 students (59%) used Hypothes.is to engage with public discourse on topics such as the causes of climate change and alternative energy sources. We found not all students could complete the in-class annotation activity in time, leaving some annotations being created without tags. In general, students mostly appreciated using web annotation to collect information and support deeper engagement with online materials. One student described:

> Using Hypothes.is has helped me think about articles more, because I know it's easy to just read them and then just forget about the stuff that you read. But when you have to make annotations and really think about the stuff that you're highlighting and making annotations about, it's a lot easier to remember information because you're like, "oh yeah I remember that [because] I made an annotation and I talked a bit about that." (Student L, Class A)

Table 2. Initial open codes of students' approaches to using the digital environment

Initial categories of open codes	Example subcategories
Technical features	● Information gathering, organizing, retrieval, note-taking (HY) ● Tagging: technical knowledge about how tags work (HY) ● Being able to see others' annotations (HY) (IM) ● Searching specific tags (IM)
Knowledge building affordances	● Using evidence in each other's annotations (HY) (IM) ● Collaborating with peers, more than knowing (IM) ● Connecting, comparing, and synthesizing ideas (IM)
Difficulties and suggestions	● Suggesting a new feature (HY) ● Suggesting to improve the search feature (IM) ● Difficulty due to wrong or unorganized tags ● More helpful if more people get involved

Note: HY—Hypothes.is; IM—IdeaMagnets.

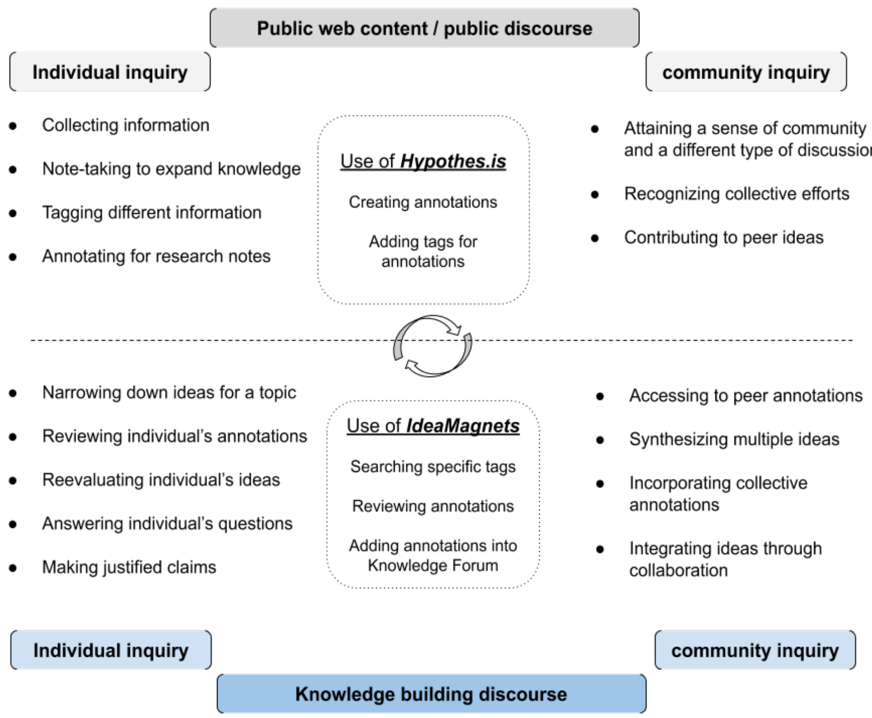

Figure 3. Learners' sense-making processes involving public and classroom discourse.

Discourse patterns involving the use of web annotation

In addition to taking advantage of the surface-level features offered by Hypothes.is (e.g., taking notes), student interviews revealed their deeper thinking about using web annotation to facilitate knowledge building at both the individual and community levels. As illustrated in Figure 3, some students created annotations on top of public discourse to expand individual knowledge. In this regard, they mentioned that by using different and more diverse tags they could increase searchability of annotations and hereby benefit their knowledge building efforts. For example, one student (Student A, Class E) suggested adding more relevant tags to her own annotations to increase the likelihood of sharing a tag with annotations made by her classmates. During this study, she was inclined to make a list of tags individually and combine them with those from the community afterwards so that "when people need to search they can have everybody's tags." Apparently, this student had come up with some unique strategies to connect personal annotations with peer contributions in the community.

Meanwhile, some other students recognized the power of using Hypothes.is as the community's knowledge base that is indexed by tags and connected with the public web. For example, one student described that "it [was] really helpful to have so many annotations," because she would not have so many resources and "everyone's work to build [on]" (Student P, Class D). Notably, students demonstrated a sense of community when annotating public sources and viewed individual annotation as a way to contribute to peer and collective ideas.

In what ways did IdeaMagnets encourage students to connect public discourse with their classroom discourse?

Actual usage and perceived usefulness of IdeaMagnets

All students used the IdeaMagnets tool in Knowledge Forum to review annotations or filter them using tags. In the Week 4 of this study specifically, 33 students (34%) used IdeaMagnets to import web annotations into their KF posts (i.e., creating *magnet-notes*). Whether the use of IdeaMagnets was to review/search annotations or to add annotation in a magnet-note, students shared they could benefit from this process when they were collectively tackling the same topic. IdeaMagnets helped them grapple with a more diverse pool of ideas grounded in public discourse, and some students developed sophisticated tag-based searching strategies to filter this pool of community annotations. For example:

> Z: Well, a lot of people were using IdeaMagnets, and a lot of people were studying copper, like me. So I was able to just go in there and find stuff that was relevant to what I was learning.
> M: It makes it easier to find stuff…
> Z: It's good to switch out which tags you're searching with. So if you're trying to find a specific source, then if you only click copper and human resource, or whatever, then you gotta switch up which ones you're in. (Student Z & M, Class E)

Discourse patterns involving the use of IdeaMagnets

In addition to reviewing or importing web annotations into Knowledge Forum discourse, students were excited about being able to integrate ideas and making justified claims in both individual and community inquiry (see Figure 3). Whether students were using a peer's annotation to tackle a research problem, they tended to synthesize multiple ideas and integrate peer ideas that stemmed from public discourse. The idea sensemaking and integration process helped the students "keep the conversation going" by continually integrating ideas connected with the public sphere (see Figure 3). For example, in Figure 4, one student (Student M, Class C) created a *magnet-note* to build on a group question "why is it called GH [greenhouse] gas" by adding another student (Student I, Class C)'s annotation into the post. In this example, Student M also continued to add her comments to summarize the main ideas from a public source. Interestingly, no matter whether students used IdeaMagnets, they acknowledged that their groups used IdeaMagnets to help answer their group questions. For instance:

> T: Well especially with IdeaMagnets, if you're making an annotation or, [magnet-note], writing thing, it was helpful to look at what other people had found about that and opposing ideas too, so you can look at what they're doing and then put that in and it would make a better answer for you.
> L: And if I wanted to learn about somebody else's topic, or if I wanted to contribute to someone else's thing, if it connected to mine I could use my own annotations but also other people's annotations that I didn't personally study. (Student T & L, Class D)

Some students also mentioned that the experience of harnessing a cluster of community ideas captured from public discourse encouraged them to continue reading web materials to add more information through tagged annotations.

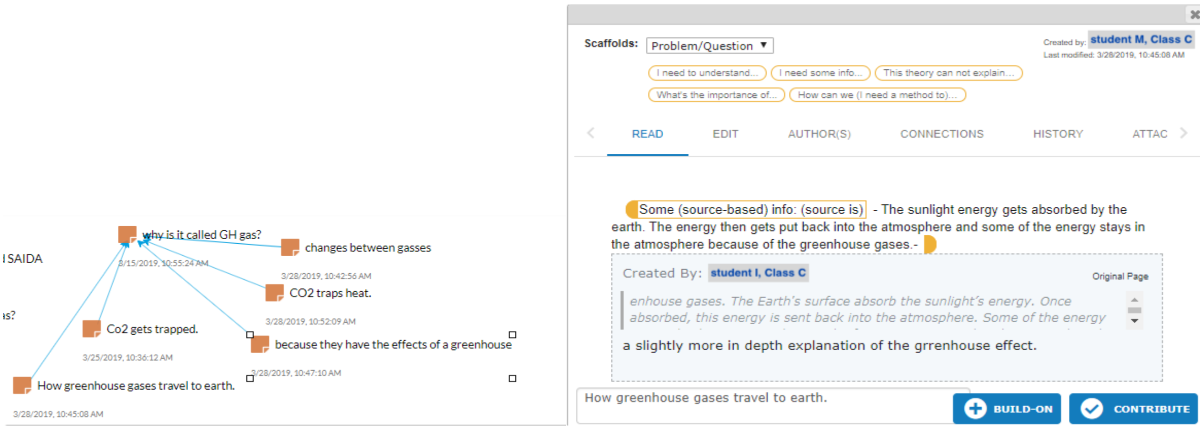

Figure 4. An example illustrated how students keep the conversation going by creating a *magnet-note* (*top*) to address a group question of "why is it called GH gas" (*bottom*).

Discussion and implications

This paper reports preliminary findings from the IdeaMagnets project that attempts to use web annotation to connect classroom discourse with public discourse. Our findings provided a snapshot of ways in which students navigated their discourse spaces and constructed understanding based on collective efforts of making sense of public materials. Discourse patterns revealed from our research data portraited two key features of the discourse supported by the IdeaMagnets tool:

- *A learning culture of annotation.* Many students found web annotation not only useful for information collection and note taking, but also for deeper engagement and easier recall. When working on their energy projects situated in the Green New Deal, they purposefully annotated information to address their research problems, as well as to index information from public discourse for easier information retrieval during classroom dialogues.
- *Purposeful and constructive use of sources.* Students highlighted that with the assistance of Hypothes.is and IdeaMagnets, they were able to introduce evidence to advance their understanding of particular knowledge problems. They recognized IdeaMagnets helped them make use of their own and each other's ideas through tag filters. As a result, they could more easily compare or connect different ideas to address various research problems.

Overall, findings from this study showed great promise of engaging students to purposefully annotate public discourse. Technologically, the IdeaMagnets tool design strengthens knowledge-building environments by extending ideas created in one context (in public discourse) into another context (e.g., KF discussions); in this case, ideas "become objects of discourse in their own right" (Scardamalia & Bereiter, 2003, p. 5). For learners, discourse processes facilitated by the tool and pedagogical design helped them navigate complex web spaces, anticipate future use of ideas when annotating web materials, and draw on each other's contributions to solve ill-defined knowledge problems. Collaboration in this context is more emergent and opportunistic, while learners are responsible for performing important epistemic tasks such as meaningfully tagging annotations, intentionally filtering annotations, and integrating multiple ideas to address knowledge problems.

The reported descriptive case study is only the beginning of an attempt to integrate knowledge-building discourse in classrooms with public discourse and societal knowledge creation. In the immediate future, we will closely examine discourse content generated from this intervention to uncover patterns of students' knowledge practices. Using the lens of epistemic cultures (Knorr Cetina, 1999), we will focus on ways in which learners create and warrant knowledge with knowledge objects from public discourse. We will also seek to build stronger knowledge-building scaffolds in web annotation tools and design and test new pedagogical strategies.

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The Research on Cultivating Vocational School Teachers' Educational Research Ability in a Knowledge Building Community

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Abstract: The novice teachers from vocational schools are normally short of educational research ability, which is the basic requirement of teachers' professional development. However, these abilities are always inhibited by traditional lecture-centered training mode. This research organized a Knowledge Building community for 42 novice vocational school teachers who are from 19 vocational schools in Nanjing, China. The KB journey started from their own authentic problems happened in their 1 or 2-year teaching experience, supported by the community meeting, knowledge building circle, knowledge building poster session and research paper discussion, after which the novice teachers raised diversity ideas and theory building of teaching and learning. Data source is from their notes on Knowledge Forum, research papers and feedback forms as well as the interview records. Content analysis and open coding are main methods. The research results indicated that these novice teachers have strong potential to do educational research and have a strong sense of teaching reflection and problem discovery, as well as deep thinking. However, due to objective conditions and teachers' own limitations, they still need to strengthen their abilities in data processing and overall planning.

Introduction

Educational research ability is the ability that teachers can solve problems in educational context effectively and they can study on students, curriculum, teaching objectives, teaching process, teaching methods, teaching strategies, teaching environment and so on (Yang, 2012). Numbers of researchers have pointed out that educational research is an inevitable choice for a professional teacher (Christie, 2006), which means that an excellent teacher not only should have abundant of teaching knowledge and skills, but also should have deep thinking ability and they are supposed to discover, analyze and solve problems. However, existing studies have shown that current teacher training still focus on teaching pedagogical theories, methods (Chang, Fang, et al, 2009). Moreover, lecture is the most widely adopted way to train teachers, which is less effective for teachers and probably lead to a decrease in teachers' participation, then miss the opportunity to foster their educational research ability. The problems are as followed that teacher training has lasted for decades, but traditional training beliefs, content and methods are still stay unchangeable. Whether this training beliefs can meet with the demands of present society?

Knowledge Building, defined as "the production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003), which is a knowledge innovation theory and also a new teaching belief, trying to cultivate teachers' research ability. In the past few decades, Knowledge Building theory has guided a great variety of teacher training programs in many countries (Hung, Hong et al, 2017; Lin, Hong, et al, 2019). Researches showed that it can help foster teachers' sense of innovation and design thinking, but whether it can promote teachers' educational research ability remained unknown.

Vocational school teacher training program is organized every year in Nanjing, China, while the effect is unsatisfying. Because traditional teacher training which highlighted teaching knowledge may not enough, at least for those novice vocational school teachers, they just get some teaching theory and experts' knowledge and they did not have their own research ability. So this research will help 42 novice teachers in 19 vocational schools, who have been working for 1 or 2 years to build a knowledge building community and start teacher training. Three research questions will be focused on:

1. What the vocational teachers' research ability is after the teaching training program based on Knowledge Building?
2. How did these vocational teachers change their research ability in the training?
3. What is the main reason for them to make changes in educational research ability?

Methodology

Research Context and Participants

This research is actually a teacher training program for novice vocational school teachers in Nanjing, which has totally 19 vocational schools, 42 novice teachers from 35 subject areas involved. The teachers all have a few teaching experiences, with 37 teachers start teaching in the year of 2019, and the other 5 teachers start teaching in 2018. 17 of them has got master degree while the other has got bachelor degree. The average age is about 26 years old. They are used to traditional teaching training before this program, they have never heard of Knowledge Building and they are not used to construct their own knowledge.

The main purpose of this training is to promote the professional development of vocational teachers, which was lasted for approximately 3 months. The training has 2.5-hour offline class every two weeks. The training guidance group is constituted of a main trainer who is an expert in Knowledge Building, studying Knowledge Building for decades; an experienced organizer who organize vocational teacher training program every year; And 4 assistants whose main duty is to observe the whole training process and feedback, as well as collecting training data.

The overall environment is relaxing and flexible, with teachers can move around freely in class, form and disband groups, participating discussions as they wish. Each teacher is required to have a laptop to join the online discussion on Knowledge Forum at any time. The trainer encourage teachers to keep their ideas on KF, so as to visualize their inner ideas.

KB Training Process

The whole training process is based on Knowledge Building and its 12 principles. During the offline training session, the experienced trainer adjust his training in time according to teachers' behavior and based on a teaching procedure mode (figure 1), trying to make teachers find problems, start deep thinking and participate in the training actively, which help to promote their educational research ability.

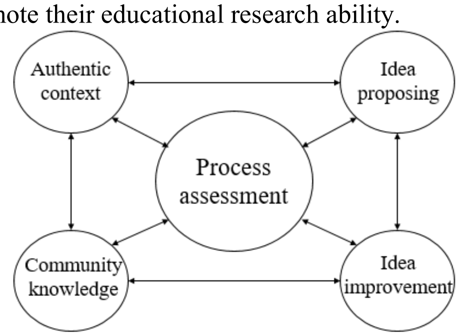

Figure 1. A KB-based Teaching Procedure Mode

The whole training was divided into 3 phases. In the phase 1, the trainer organized a series of activities, like each teacher needed to talk about their confusion about teaching. For instance, "are the teaching strategies reasonable nowadays? What is the nature of teaching and learning? Is there a conflict between teaching theory and practice?" they just come up with a great variety of interesting teaching problems and they were required to post notes on Knowledge Forum and have offline discussions. The trainer seized the opportunity to discuss about how to demonstrate ideas. Therefore, teachers' discussion started transforming from shallow construction to deep construction.

In the phase 2, it was obvious that teachers were stuck in a situation that they just described what the problem is and they cannot find out ways to solve it, which make the development of teachers' research ability stay still. Thus, the trainer have a deep discourse with all the teachers in a meta-cognition level about how should we do the research, how can we understand others and give others reasonable suggestions on Knowledge Forum, after which we also provide numbers of scaffoldings, like "what I have known about the existing theory related to the problems; I think this theory cannot explain…" Finally those scaffoldings help teachers to transform their abstract expressions into concrete expressions. In addition, the trainer also introduce some excellent teaching cases in order to widen teachers thinking. The teaching theory of ADDIE (Analyze, Design, Development, Implement, Evaluate) was taught by the trainer and poster sessions were organized to foster the interaction (figure 2).

Figure 2. Teachers' artifacts in poster sessions

In phase 3, we all hoped to further promote teachers' educational research ability by asking teachers to reflect on their own research questions in the community. So several poster sessions were held and in the sixth offline class, we organized the Knowledge Building circle to discuss teachers' research paper. So all the teachers were set in four groups and propose their ideas and have Knowledge Building discussion, after which write down the group reflection. In the seventh offline class, teachers all finished their research paper and have the whole class meeting to talk about their study.

Data Collection and Analysis

The educational research ability include the awareness of teaching problems; analysis of teaching problems; and problem solving ability. The data source is KF notes, teachers' research papers and their feedback forms.

1. The dimension of process: using content analysis to analyze teachers' KF notes

There are totally 6 views on KF, namely Analysis, Design, Development, Implement, Evaluation and Others.

Table 1: Contributions in each view

View	Analysis	Design	Development	Implement	Evaluation	Others	Total
The number of notes	92	52	1	37	10	123	315

In order to evaluate teachers' educational research ability, this research use and modify a coding scheme to represent educational research ability (table 2) and do the content analysis based on 315 notes. In order to make sure the validity, two raters had independent analysis, and Cohen' Kappa is 0.86, which means the result has good validity.

Table 2: Coding scheme to evaluate teachers' educational research ability

Categories	Sub-categories		Coding
Awareness of teaching problems based on practical reflection	Reflect on teaching activities, realize the advantages and disadvantages and find out the teaching problems.		A1
	Analyze the difficulty, feasibility and research value of the teaching problems.		A2
	Summarize and rise above the teaching problems into a clear research topic.		A3
Analysis of teaching problems based on rational understanding	Find helpful, authoritative and up-to-date materials through multiple ways.		B1
	Classify and summarize research materials.		B2
	Think critically about existing research about problems and extract effective and critical information.		B3
Problem solving based on systematical logic framework	Ability to use research methods	Select the appropriate research methods according to the characteristics of the research problem	C1
		Combine various research methods together according to research needs	C2
	Ability to design research proposals	Design the whole research framework based on the selected research methods	D1
		Design concrete implementation steps based on research ideas	D2
		Reflect on the research plan and make adjustment and modification	D3
	Ability to process data	Collect data related to the implementation process in time	
		Filter the collected data, identify and classify the valid data, and	

		understand the functions of different data	
		Analyze data using words, figures, graphics, etc	
		Dig out effective data and summarize the reasons and nature behind the phenomenon	
	Ability to express and reflect on research findings	Analyze the research results, using teaching theories to demonstrate the research conclusions	
		Express the findings in a understandable way	
		Reflect on the research results and transform them into specific teaching strategies	

2. The dimension of training outcomes: using content analysis to analyze teachers' research paper

In this training program, each participant was required to submit a research paper. 36 valid research paper were collected at the end of this training, excluding 4 papers that were unrelated to the theme. In order to make a summative evaluation of teachers' educational research ability from the perspective of final outcomes, the research used the analysis scale shown in table 2 above. Each category has five grades, namely 1-5, and these 36 papers were then scored by two researchers to ensure the validity of the final grades.

3. The dimension of explanation: using open coding to code teachers' feedback forms

In order to analyze the reasons why teachers' research ability has changed, this research try to have collective reflection session and individual interview at the end of the training to dig out deeply about the reason. The collective reflection was carried out in Knowledge Building circle which has already mentioned and 32 valid reflection records.

After the sixth offline training, semi-structured interviews were organized. 7 teachers who are typical in class performance were picked to be asked several questions that based on interview outline. The whole process of interviews were recorded which has approved by these teachers and transcript them into text. The reason to pick up these 7 teachers is that 2 of them had active attitude all the time and finish all the tasks as they could; 3 of them perform in an average level and the number of their notes on KF were in an average level as well; while the other 2 of them were not active and they always leave the training early.

As for the interview data and reflection documents, this research try to use Nvivo software to code all the information. The brief of coding is to read all the data and create nodes as needed and merge as well as group these nodes into related categories. Two researchers were participated in the open coding work.

Results

1. From the dimension of training process, teachers have deep inquiry while still lack of overall planning ability

This research analyzed 315 notes excluding 87 notes that were unrelated to educational research ability using the coding scheme shown in table 2. The analyzed results are in table 3. It is found that during Knowledge Building discussion, teachers reflected more on current teaching activities (totally 72 notes) and they can critically think about the information (totally 71 notes). All these data indicated that the teachers were buried themselves in active learning and researching, they were thinking deeply about the advantages and disadvantages of teaching, which has already seems to be different from what they performed before. But from table 4, the notes that are about overall planning and proposal designing are still a few, which can be inferred that teachers are still lack of the ability to combine different teaching strategies.

Table 3: The numbers of notes in three different dimensions

Awareness of teaching problems			Analysis of teaching problems			Problem solving				
						Strategies applying		Proposal designing		
Reflect on teaching activities to find problems	Analyze the difficulty and value of the problem	Summ-arize the topic of the study	Find information in multiple ways	Classify and summarize research materials.	Critically select useful information	Choose appropriate teaching approaches	Combine multiple approaches	Design overall frame-work	Design specific steps	Reflect and modify the proposal
72	20	22	33	10	41	20	3	4	2	1

In addition, notes in different views in three phases were collected and compared. Figure 3 showed the results. Research found out that as training going on, the percentage of notes that are about reflection and analysis about the difficulty of a teaching problem is reduced gradually, while the percentage of notes that concentrated on analyzing and solving problems rise rapidly, especially in the third phase, the percentage of analyzing reached 50%.

The percentage of notes about problem solving has also risen from 5% to 20%, which indicate that teachers propose numbers of problem in the first phase, while in the second and third phase, they were investigating and thinking to further their research. Thus, it can be inferred that they have really buried in educational research.

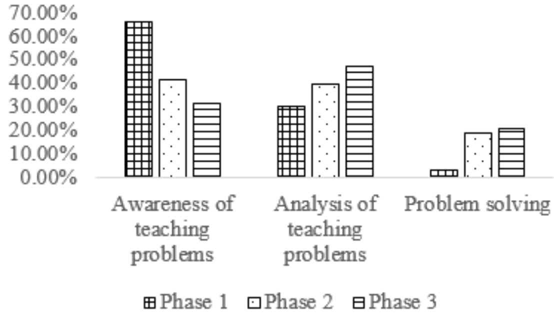

Figure 3. Percentage of notes in three different phases

2. From the dimension of training outcomes, teachers have strong sense of discovering teaching problems

The score of teachers' final research paper were assessed by several researchers based on table 2. So the final result is showed in table 4, which indicated the final result of teachers' educational research ability.

It is found out that teachers have the highest score on reflecting and summarizing topics (around 3.3). They were thinking deeply when finish their research paper. But teachers performed not so well in other aspects especially on data processing, which refers that except to provide them free research environment to enhance their problem awareness and analytical ability, the techniques and methods of data processing are also needed to promote their educational research ability.

Table 4. The score of teachers' research paper

			Average Score	Standard deviation
Awareness of teaching problems		Reflect on teaching activities to find problems	3.33	1.10
		Analyze the difficulty and value of the problem	3.00	1.15
		Summarize the topic of the study	3.31	1.17
Analysis of teaching problems		Find information in multiple ways	2.47	1.03
		Classify and summarize research materials.	2.28	1.00
		Critically select useful information	2.17	1.03
Problem solving	Strategies applying	Choose appropriate teaching approaches	2.47	1.08
		Combine multiple approaches	1.94	0.98
	Proposal designing	Design overall frame-work	2.31	0.86
		Design specific steps	2.31	0.95
		Reflect and modify the proposal	1.89	0.89
	Data processing	Collect data related to the implementation process in time	2.08	1.16
		Filter the collected data, identify and classify the valid data	1.92	1.05
		Analyze data using words, figures, graphics, etc	1.81	0.92
		Dig out effective data and summarize the reasons and nature behind the phenomenon	2.11	0.98
	Express and reflect on research findings	Analyze the research results, using teaching theories to demonstrate the research conclusions	2.28	0.85
		Express the findings in a understandable way	2.53	0.77

		Reflect on the research results and transform them into specific teaching strategies	2.28	0.94

3. From the dimension of explaining, Knowledge Building can help teachers foster their educational research ability because of its atmosphere and beliefs

From the perspective of process and outcomes, it is clear that teachers' thinking ability has improved greatly, while they are still deficient in detailed research process. In order to find out the reasons, the collective reflection documents and interview records were analyzed via Nvivo software and did open coding work by researchers. The final result is in table 5.

Table 5. The coding results of the reason teachers' changing research ability

Parent node	Child node	Child node
advantages	Training mode (21)	High engagement (3); Continue to think (1); Guidance by trainer (8); Thinking deeply (6); organizing thoughts (1); Potentialities exploiting (1); More ideas (1)
	Peer pressure and help (14)	Different opinions (10); Reflect on others' ideas (1); Conclude others' ideas(1); Peer inspiration (1); Supplement with peers (1)
	Individual factors (2)	Self-efforts (1); Self-study about teaching theory (1)
limitation	Approaches (5)	Lack of quantitative approaches (4); Difficulty in finding literature (1)
	Difficulty in relating practice (11)	Difficulty in the teaching content (1); Theory cannot relate to practice (2); Hard to popularize (1); Hard to deeply improve (1); Difficulty in activate students (6)
	Objective condition (23)	Lack of partners (2); Lack of resources (5); Limitation in the training duration (2); Lack of data (9); Limitation in subjects (2); Teaching pressure (3)
	Self - imitation (15)	Have little knowledge of teaching (2); Lack of time (7); Lack of confidence (3); Have no awareness of reading literatures (1); Lack of teaching experience (2)

Note: the number in brackets mean the number of nodes

The research found out that teachers thought Knowledge Building has increased their participation of training (3 nodes). They believe that under such atmosphere can they think deeper about teaching problems (6 nodes) and get different opinion from other teachers and help each other (14 nodes) to improve their educational research ability. Therefore, KB-based teacher training can gradually help teachers to absorb in researching because of a unique research atmosphere and its strategies.

On the other hand, there still exist numbers of limitation. It is found out that teachers did not have a good command of overall planning, literature reading, data processing and paper writing ability. Because teachers have a little understand of some theoretical methods, like they know a little about the quantitative approaches (4 nodes); the students are hard to handle (6 nodes) and their own limitation (15 nodes) as well as some objective condition, which make it difficult to balance the research and their teaching.

Conclusion and Discussion

This research try to improve vocational school teachers' educational research ability in Knowledge Building community. Thus, a three-phase Knowledge Building training mode was designed to make teachers absorb in a researching atmosphere that is good for them to raise and reflect on educational problem and increase the interaction among teachers to support deep thinking and discuss reasonable research plan and teaching strategies, which is an innovative attempt that is quite different from the traditional lecture-centered teacher training.

This research analyze the reason why teachers have changed on educational research ability and evaluate the effect of this training from three aspects of process, outcomes and explanation. It is found out that there are challenges and chances in this KB-based teacher training attempt. As for the chances, Knowledge Building can do increase the participation and provide them possibilities to think and develop. While as for the challenges, this training program did not realize the self-limitation of teachers and some objective condition, which means that in the future study, an investigation toward teachers' background needs to be carried out. Moreover, a reasonable duration for the training program is also needed in order to overcome some objective problem.

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Knowledge Use in Knowledge Building Discourse

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Abstract Although many research on knowledge building process is caried out, still little is known how the knowledge information is used in the knowledge construction discourse, i.e. the use of knowledge information that we provide in education or the 'valid knowledge sources' (scientific and professional literature, experts). The use of authoritative knowledge sources is one of the principles of knowledge construction. To explore this gap, KBDeX network analyses have been carried out into the way in which two MEd student groups from a Masters in Learning and Innovation use 'curriculum' literature in their knowledge-constructing dialogues. On basis of the analysis crucial phases/activities patterns in the discourse could be identified. These discourse activities concern: Group forming: sharing everyone's 'acquired' insights and finding a substantive socio-cognitive match; Collective engagement: loosening one's own egocentric perspective and becoming involved in a collective knowledge construction dialogue; Grounding: 'dialogue' about what exactly everyone means with seemingly clear terms that are used; Integration and construction: accommodation, creation of collective and therefore own ideas by integrating and connecting ideas that transcend previous ideas (rising above); and finally writing or creating the conceptual artifact. The transition from one discourse activity to another seems to be supported by "bringing-our-knowledge-together" transgressions. These are contributions in which a state of affairs is drawn up and relationships are established between topic terms and their own ideas at that time. The results support the idea that learning is a psychological process and that knowledge emerge in students' actions in particular in their in-(ter)-actions with each other and in their world.

Introduction

Diverse studies have analyzed the knowledge building discourse. For instance Ma, Matsuzawa, & Scardamalia, (2016) found patterns of temporary rotating leadership in their analyses of social networks in knowledge-constructing conversations of primary school students. They discovered a relatively decentralized student network. Van Heijst, de Jong, van Aalst, de Hoog, & Kirschner (2019) studied the socio-cognitive dynamics in knowledge building discourse of MEd students in a master's in Learning and Innovation from the perspective of openness. In general, moderate openness was expressed in the contributions in the students' virtual conversations. The social openness appeared to be much higher in the contributions than the cognitive openness. It is all the more striking that of the four social and four cognitive expressions of openness in the student contributions, three of the cognitive openness expressions led to more follow-up contributions in the knowledge-constructing conversations than the social openness expressions. The social openness expressions appeared to have no effect at all on the continuation of a conversation.

Despite this kind of studies and those of others (Thomas, Li, Knott, & Li, 2008; J Zhang, Chen, Tao, Naqvi, & Peebles, 2014; Jianwei Zhang et al., 2014) there is still little insight into how the knowledge information offered in a curriculum is used in the discourse activity of knowledge construction, i.e. the use of knowledge information that we provide in education. In terms of knowledge building principles: the use of 'authoritative knowledge sources' (scientific and professional literature, experts) (Bereiter, 2002; Paavola & Hakkarainen, 2005; Scardamalia, 2002; Scardamlia & Bereiter, 2014). De Jong, (2019, 2020) looks at these resources as information sources (cold knowledge) which are transformed into (warm, meaningful) knowledge by students' actions. So, also by the actions in students' in-(ter)-actions. Such as, for example in the knowledge building dialogues. The process can be sketched as meaning making interaction process involving – in an almost phenomenological sense – letting 'that which shows itself be seen from the way it shows itself' (Heidegger, 1977, p. 34). Also, Gal'perin sees, building on Vygotsky's attention to speech, signs and symbols (their semiotically mediated meaning-making) and Leontiev's notion of 'activity', action as the basis for developing the meaning of these semiotic tools. According to Leontiev, the human mind has its origins in external activity from which it transformed. Thus, the human mind is not something relative to external activity. For him, human cognition and external activity are products of one another (Engeness & Lund, 2018). Heritage ((2012)) says that epistemic or knowledge positioning occurs in conversational turns through the actions in a dialogue. This contrasts with knowledge as a hidden individual, internal, mental action. Coulter (1983, p. 128) had already argued that 'people's *"mental" properties should be seen as originating from situated, constitutive (qualifying, conditioning and founding) practice"*. This knowledge positioning is calibrated in social interaction with others (recipient-designed), who monitor, actively test and respond to the stance taken (Mondada, 2019).

To explore this meaning making process in students' in-(ter)-actions during knowledge building dialogues, KBDeX network analyzes (Jun Oshima, Oshima, & Matsuzawa, 2012a) have been carried out into the way in which two MEd student groups from a Masters in Learning and Innovation use 'curriculum' literature in their knowledge-constructing dialogues. Questions in the study were:

- What role does that information from authoritative resources, i.e. topics, concepts, words that cover the topics in the literature (topic terms), play in the in-(ter)-actions that students use to develop their conceptual artifact?
- What is the nature of the actions in which those topic terms perform their connecting function during the discourse?
- What does this say about the in-(ter)-actions and the process of knowledge emergence?

Method

The data comes from online discourse contributions in the interactions of MEd master students in the trimester course building their vison on learning. It can be deduced from the instruction of the course component that it is more about an "idea-centered" activity than a "task-centered" activity:*"(...) the most important starting point is knowledge creation. The fact that teachers want to join them in a knowledge creation process leads to collective and individual insights. Insights that arise from a "design mode" to deal with information.* (..)" (Course introduction to students in the course manual, 2019). This indicates that the focus of the course is not on the most beautiful representation of theories, but on the elaboration of the ideas of students they have gained by reading and working with those theories. *"(...) Obviously, that requires a good understanding of it.(…)"* (Course introduction to students in the course manual, 2019). Scardamalia (2002) calls this constructive use of authoritative sources. It is a process from the "collective idea" to your own ideas and vice versa. *"Another important starting point for the course is that it is about" (...) describing "learning" as a phenomenon, as a process. For this it is not only useful to gain a lot of insights, but it is also necessary to know your own vision and views on learning and to test what you will be encouraged to do."* (Course introduction to students in the course manual, 2019).

Subjects

Two subgroups of N=4 students each, that were the most active in online discourse were selected from a year cohort. Active in the sense that both groups had substantial amount of contributions in a Knowledge Forum dialogue environment as a group N= 192 and N=191contriubutions. Each subgroup comprised three women and one man between the ages of 26 and 55. Students all had a working position as a teacher or as human resource developer. They followed this two-year part-time MEd Learning and Innovating program in order to professionalize oneself in innovating their practice. (because of European privacy law we cannot give further detailed information).

Analyses

To analyze the constructive connections, we used KBDeX (Knowledge Building Discourse eXplorer), a content-based social and temporal network analysis tool (Jun Oshima, Oshima, & Matsuzawa, 2012b). The present analyses concern the relationships between the semantic, social topic terms that have been created. They concern relationships that arise as students build on one another's input –in other words, shared ideas through the co-occurrence of topic terms in discourse contributions. The advantage of using KBDeX and co-occurring terms is that it makes the form of the connection transparent, thus making it easier to investigate the semantic connections in their network of the dialogue. This maximizes the transparency of knowledge-building processes. Other studies have also used co-occurring term concepts via semantic analyses to test knowledge development (Hong & Scardamalia, 2014; Ma et al., 2016; Matsuzaw, Oshima, Oshima, Niihara, & Sakai, 2011).

The KBDeX social semantic network analysis (SSNA) method was crucial in the analysis because our data source was the Knowledge Forum dialogues conducted by the Master of Learning and Innovation students within the Learning theme with a view to arriving at a collective vision of learning. Students shared their ideas in the Knowledge Forum by posting contributions in a two-dimensional, virtual, collective workspace.
The students' online discourse discussions were imported into KBDeX in order to perform the content-based social semantic network analyses (SSNA). KBDeX allows us to investigate discourse in real time. For example, if you click on a key term in the word network, the discourse units in the discourse unit network in which the key terms simultaneously occur will also show up in red, and so too will the authors of the discourse units. (see Figure 1).

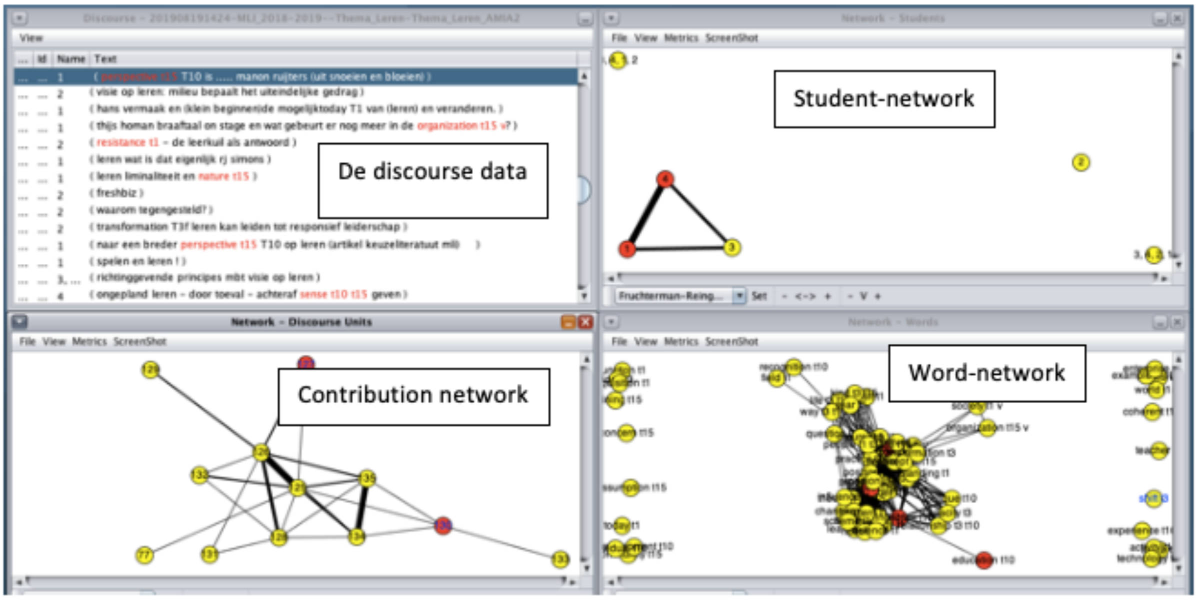

Figure 1, KBDeX window: The thickness of the lines shows the strength of the relationships, calculated on the number of discourse-paired units that share a term.

This functionality was used to investigate the discourse in depth as a way of validating the strength of the betweenness centrality value, based on Natural Language Processing (NLP), topic modelling and topic terms. The 'centrality' indicates the importance of a discourse unit, a term (concept) or an individual in the contribution to and the strength of the network (see also (Ma et al., 2016; J Oshima, Matsuzawa, Oshima, & Niihara, 2013; Jun Oshima et al., 2012a). The higher the centrality value, the stronger the contribution to the network's development. A centrality value of 1 means that the influence, proximity, or contribution to the network is high, whereas a value of 0 means that there is no influence or proximity, or that no contribution is made. Thus, if a discourse unit integrates previous ideas, it contributes more to proximity and degrees of centrality coefficients than ones that integrate fewer or no ideas.

The knowledge construction productivity and creativity are interpreted by the decentralized network structure through the firm adherence to certain topic terms that are leading. Analogous to the rotating leadership phenomenon in a social network (Ma et al., 2016), it can be assumed that the changing connecting force in the course of the interaction of available topic terms in studied authoritative sources has a meaning in this. Topic terms that remain in the periphery of the discourse make little contribution. Topic terms that regularly change from the periphery to the core of the discourse, on the other hand, make a strong contribution to productivity and creativity, and thus to the success of knowledge development in the in-$^{(ter)}$-action.

We took the core literature from the set texts, namely Illeris' (2009) Contemporary theories of learning. The students were asked to study Chapters 1 (Illeris), 2 (Jarvis), 4 (Engeström) and 10 (Tennant) for the second session in the first month and Chapters 3 (Kegan), 6 (Mezirow), 15 (Lave & Wenger) and 16 (Wildemeersch) for the third Learning theme session in the second month. These chapters were subjected to an NLP topic modelling analysis (see Figure 2). The rationale behind topic modelling is that meanings are relational (Joseph, 2011). Topics are associated with a group of words that occur frequently (Ignatow & Mihalcea, 2016). The resulting group of words can also be interpreted as lexical fields, groups of words whose meanings depend on each other; together, they form a conceptual structure that is part of a particular activity or specialist field

(Geeraerts, 2010; Saeed, 2015), such as a lexical field associated with school (e.g. teacher, book, notebook, pencil, student, etc.).

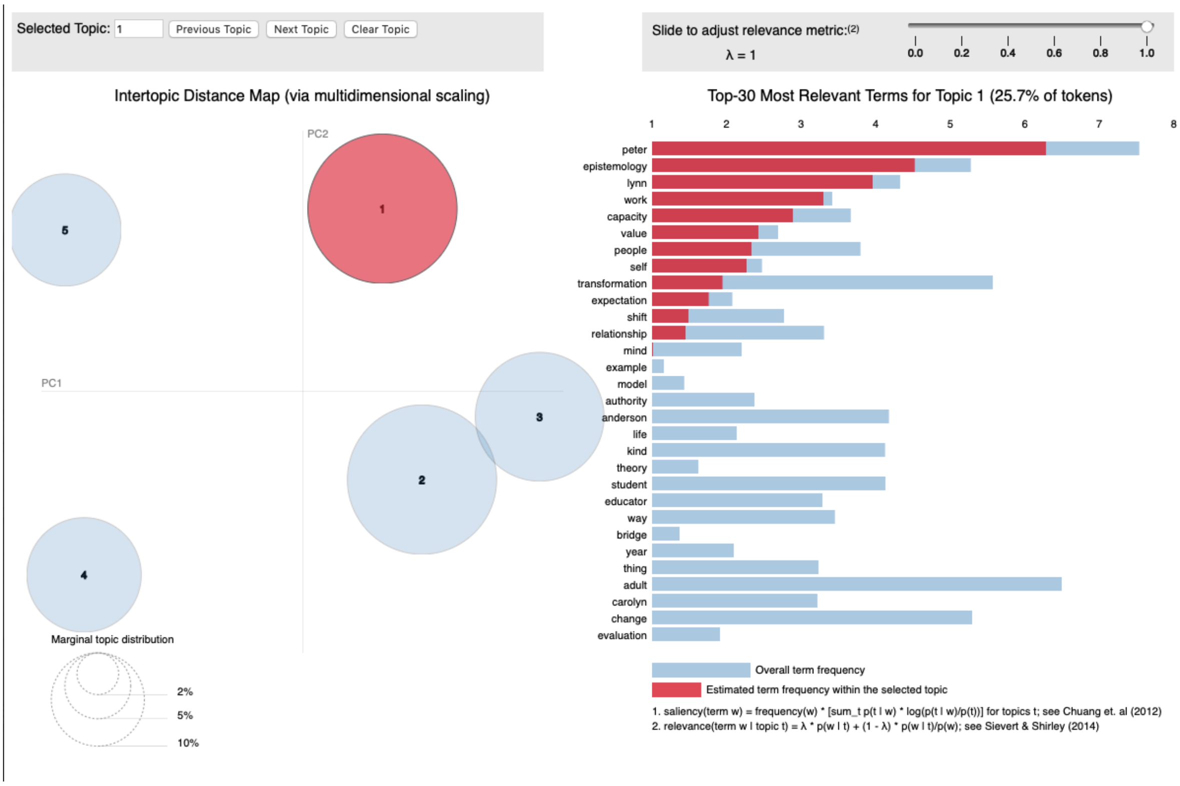

Figure 2. NLP topic modeling of one of the chapters in Illeris (2009), Contemporary theories. Blue represents the total frequency and red the estimated frequency of the term within the selected 'topic'.

For the SSNA used in KBDeX, for each chapter, we selected the most frequent terms in all topics in the chapter. For the analyses, we selected two chapters that students were asked to study for the second session (Chapters 1 and 10) and two (Chapters 3 and 15) for the third session. Chapter 1 was chosen because it sets out Illeris' overall theory and all students were likely to have read it. The other chapters were selected because they closely aligned with the visions of two selected subgroups of students. This also created a balance between the first and second periods of study, and in the distribution of chapters across the book. Chapter 1 has a strong constructivist, cognitivist orientation. In chapter 10, Tennant emphasizes a strong postmodernist view of eliminating the dualism between object and subject and post-humanist 'self'-orientation. Chapter 3 presents Kegan's strongly epistemic transformative vision of learning. Chapter 15 deals with the social learning theory of Wenger's communities of practice (COP). Also included in the SNA alongside the topic model terms for each subgroup were terms that the group 'appropriated', in students' visualization of the collective vision of learning, their conceptual artefacts.

Results

The betweenness centrality was examined at topic-term level for each group. In Figure 3, the y-axis shows the betweenness centrality value and the x-axis shows the time. Each topic term is represented by a colored line. The oscillation of colored, overlapping lines shows the rotating strength of connection of topic terms. This means that the connecting term concept with the highest centrality value at any given time changes frequently during the discourse.

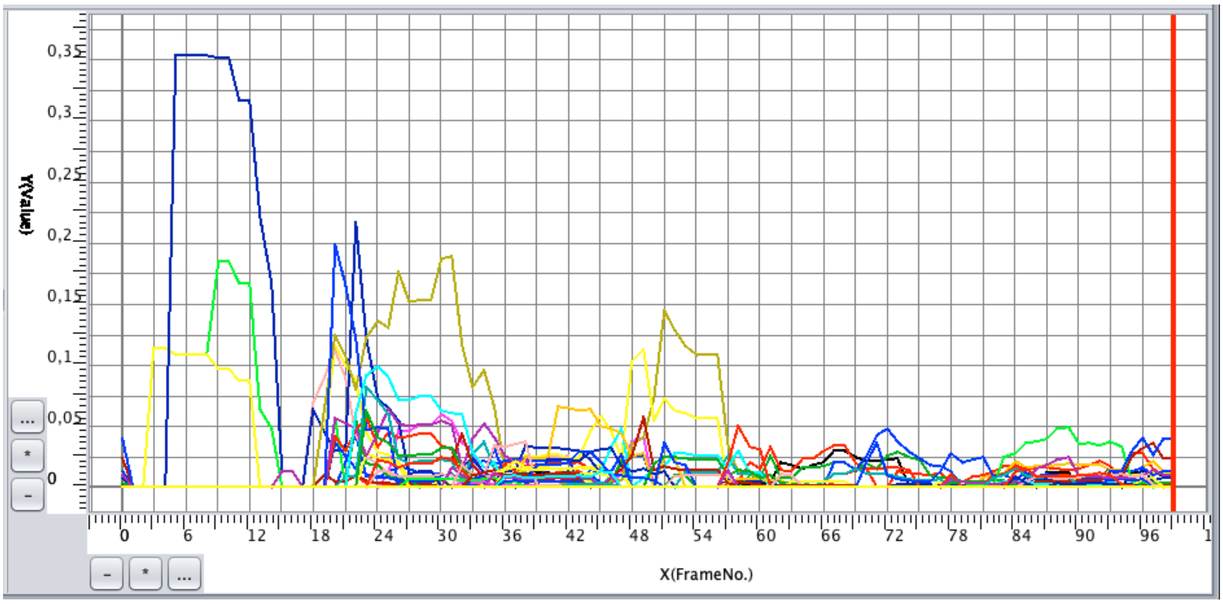

Figure 3: The between centrality at term level in the word network for group A

Of the 117 term concepts in the analysis of Group A, 13 function to a greater or lesser extent in a constructive, connecting position. Of these, six have a maximum betweenness centrality of more than 0.10: Knowledge (v) 0.353, Result (t1) 0.198, Organization (t15/v) 0.188, Community (t15) 0.184, Team (v) 0.116 and Position (t10) 0.112.This means that these topic terms had a 'connecting' function during the discourse, or knowledge building dialogue. The other somewhat connecting terms had centrality values of <0.067 and > 0.035, or even zero (v = a key term in the students' conceptual artefact; t15= a key term coming from the NLP analyses chapters where the number indicates the chapter).

Of the 118 key term concepts in the analyzes of group B, 11 are functioning to a greater or lesser extent in a constructive connecting position (see Figure 4), 2 of which have a centrality value above 0.1: Way (t3, t10, t15) 0.444; Notion (t10) 0.243. This means that these two topic terms were the most strongly "binding" in the course of the discourse or the knowledge-constructing dialogue. The other topic terms had a centrality value between <0.076 and> 0.043 or even zero.

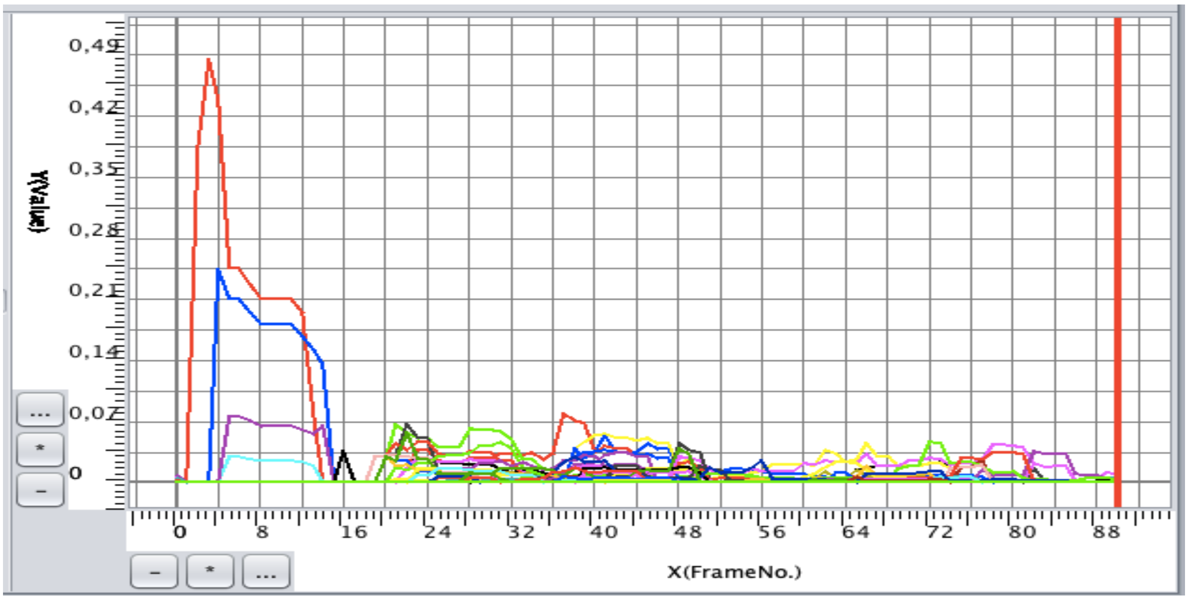

Figure 4. The between centrality at term level in the word network for group B

Inspecting Figures 3 and 4, we indeed see that in the starting phase of the discourse both groups are strongly influenced by certain topic terms. In the subsequent discussion activities, group A was more strongly influenced by certain topic terms that linked the sub-dialogs than group B. In the activities at the end of the discourse, the two groups appear to be more equal. We also see that in the visualization of the topic terms in Figure 4 where group B is much more diffuse in its topic terms and group A uses more compact topic terms in its vision construct. Although the groups studied the same literature, we see that both groups only use the same topic terms in their discourse: Position (t10) and Process (t1 t10 t15).

The differences of the visual inspection are confirmed in a MANOVA analysis with the connecting centrality as a dependent factor and the groups A and B as a group factor. There appears to be a significant effect in the connecting centrality of the overall topic terms. So not all concepts are equal in their unifying force in the discourse. There is also a significant effect between groups A and B in the connecting centrality (see Table 1).

Table 1: MANOVA results with the betweenness centrality values as within factor and group as between factor.

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	,889	16,493[b]	62,000	128,000	,000	,889	1022,583	1,000
	Wilks' Lambda	,111	16,493[b]	62,000	128,000	,000	,889	1022,583	1,000
	Hotelling's Trace	7,989	16,493[b]	62,000	128,000	,000	,889	1022,583	1,000
	Roy's Largest Root	7,989	16,493[b]	62,000	128,000	,000	,889	1022,583	1,000
group	Pillai's Trace	,884	15,707[b]	62,000	128,000	,000	,884	973,840	1,000
	Wilks' Lambda	,116	15,707[b]	62,000	128,000	,000	,884	973,840	1,000
	Hotelling's Trace	7,608	15,707[b]	62,000	128,000	,000	,884	973,840	1,000
	Roy's Largest Root	7,608	15,707[b]	62,000	128,000	,000	,884	973,840	1,000

a. Design: Intercept + group

b. Exact statistic

c. Computed using alpha =

Qualitative analysis of the students' contributions connected to the key terms at the moment the key term has a high degree of betweenness centrality value exposes different phase or activity during the discourse. Group A's discourse is characterized by the use of many 'authoritative' sources. From their focus on Illeris, it is mainly chapters 1, 3, 10 and 15, and the students' 'own' concepts from their vision, such as Knowledge, that played a connecting, constructive role from the beginning in developing their vision of learning. For instance, at the discourse in this group unit containing the topic term Community, we see that both Students Three and Four made a contribution. Student Four integrated (the activity) in turn 4, in particular with Community and the topic terms Team (v), Structure (t15), School (t1 t13) and Knowledge (v) (see Figure 5). Student Three integrated (the activity) in turn 2, in particular with Community (t15) and the concepts Question (t10), Team (v), Self (t3, t10) and Process (t1, t10, t15) (see Figure 6). Both students also contributed in relation to the topic term Team (v) in their turns (2 and 30). A little later, Knowledge (v) played a connecting role in the turns of students One and Four. This had already happened with Student Four (turn 30), who, when describing their innovation in their work context, integrated in particular (cognitive) Knowledge (v) with Community (t15), Team (v), Structure (t15), School (t1 t13) and Practice (t10 t15) (see Figure 7).

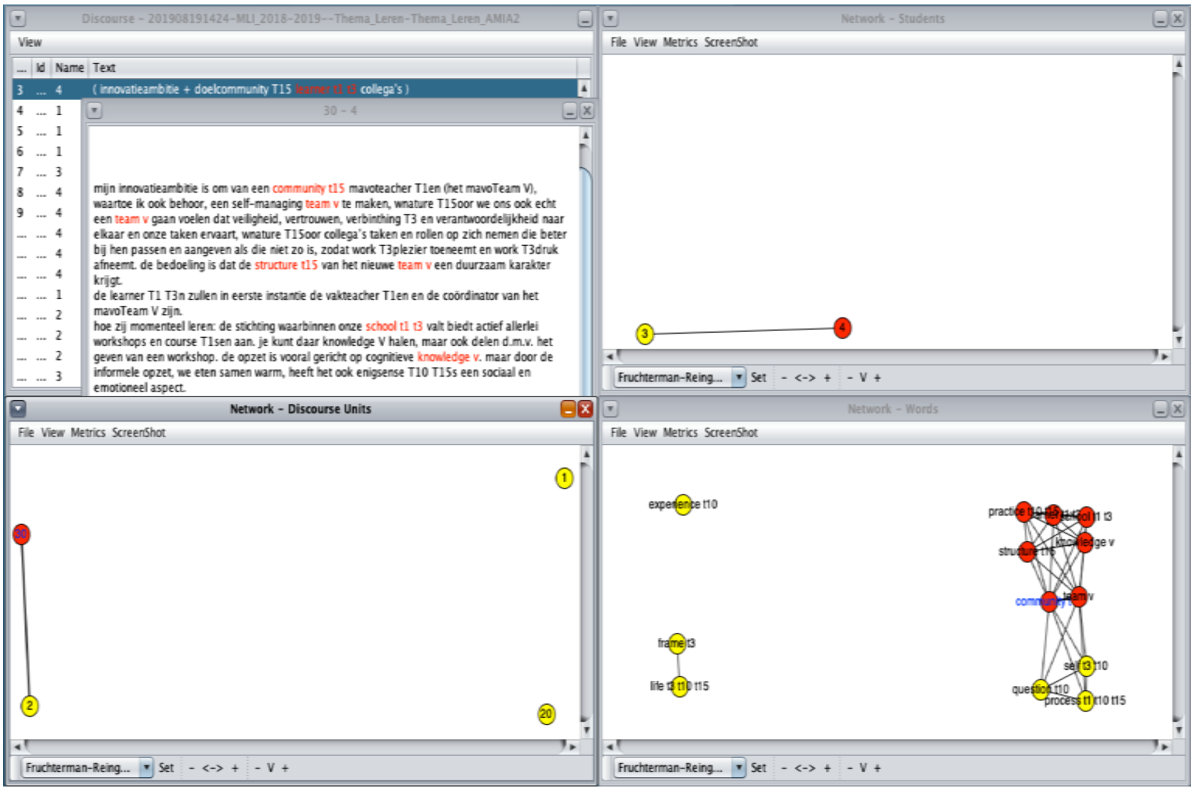

Figure 5: Student Four's turn, with a high betweenness centrality for Community and Team

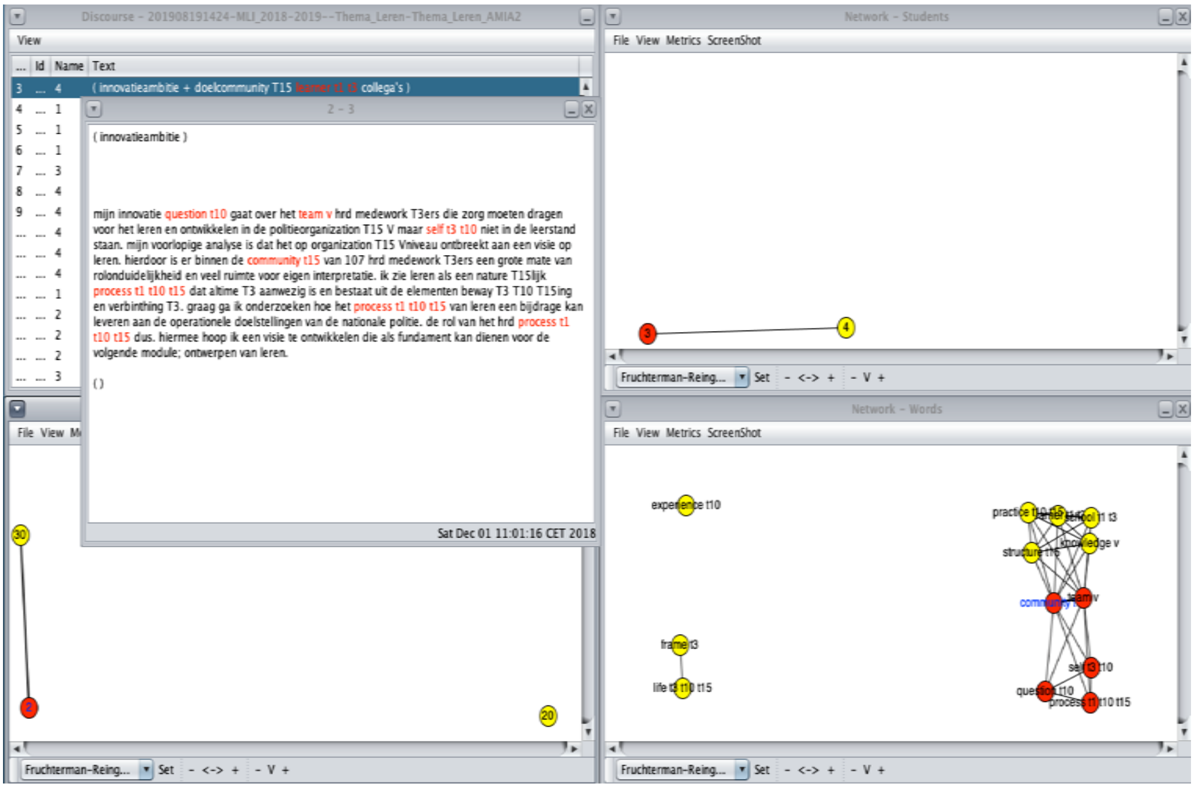

Figure 6: Student Three's turn, with a high betweenness centrality for Community and Team

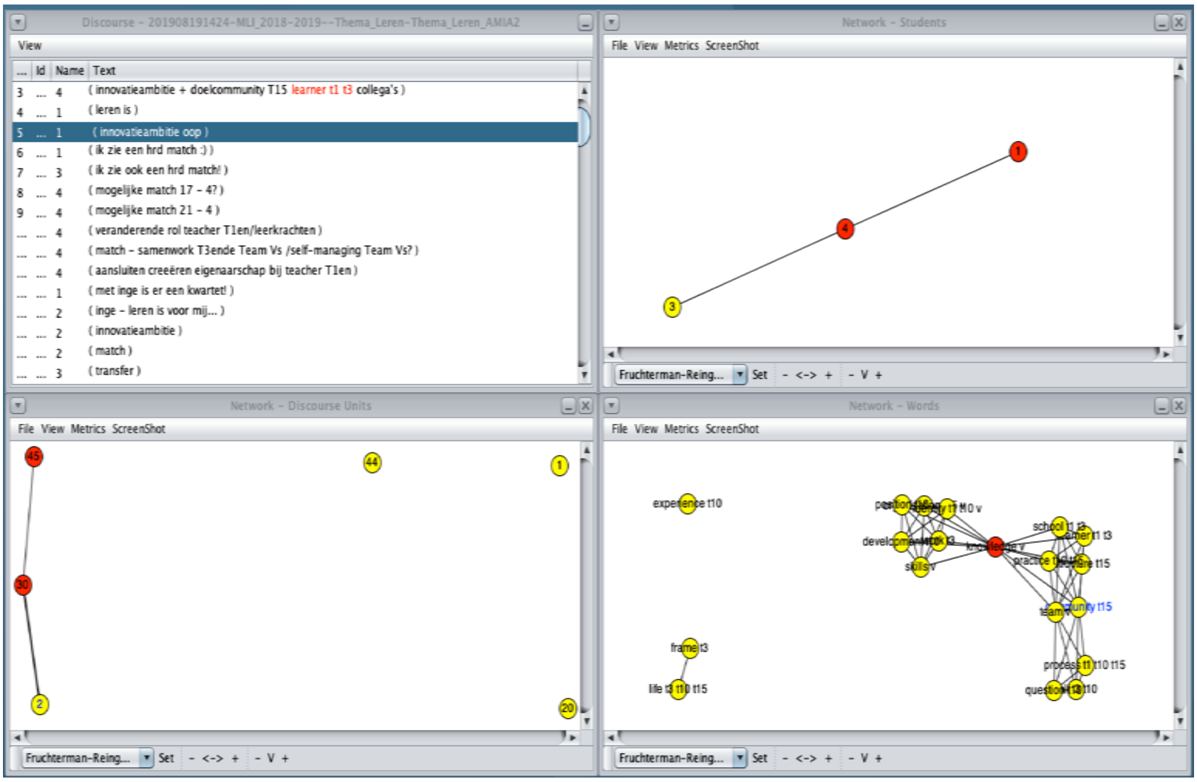

Figure 7: The betweenness centrality of Knowledge in the discourse

So, at the beginning of the discourse, we see a strong conceptualization based on their own work and experience practice. This transforms into an activity from a collective focus, in which students acquired an interest in shifting from a personal to a collective perspective. This is followed by a grounding activity in which the students deepened the concepts and made them explicit. This 'deepening' occurred through the use of authoritative literature. A contribution involving 'bringing our knowledge together' introduced the final stage of the discourse, in which concepts were increasingly integrated and authoritative sources expanded. This occurred with a strong focus on a clear collective, as well as individual, accommodation of ideas in the creation of their collective concept of 'learning' and their vision as a expressed in their conceptual artefact: *"The circular or elliptical movement in our model represents the phase of chaos (searching), the phase of defining, redefining, dialogue, testing and adjusting the frame of reference, new epistemologies, or transition.' "Learning" is essentially making meaning'. 'Our vision thus includes the paradigm of meaningful interactions of wholeness (the external and internal learning process is one and the same spectrum of "learning")*'.

Group B's discourse is characterized by a brief activity that moves from individual to collective engagement (Figure 8, lower picture), as well as by a very lengthy grounding activity that continues until the end. This involves summarizing the theory and guest lectures and, towards the end, alternating or parallel personal opinion-forming and meaning-making (about what they felt was meaningful) and the creation of their collective vision. Thus, in the final 'bringing our knowledge together/rise-above' we see more topic terms that also appear in the conceptual artefact. Group B adheres closely to the literature in their discourse and in their description of their vision of 'learning'.

The connecting role of the topic terms serves different activities in the knowledge construction process (see fig. 8):

1. Identify a socio-cognitive match;
   Breaking free from the egocentric perspective and become involved in a collective knowledge construction dialogue;
2. Deepening by 'grounding': 'What does someone mean by a term?';
3. A moment of 'bringing-our-knowledge-together';
4. In-depth final activity of Accommodation, creation of collective and own idea.

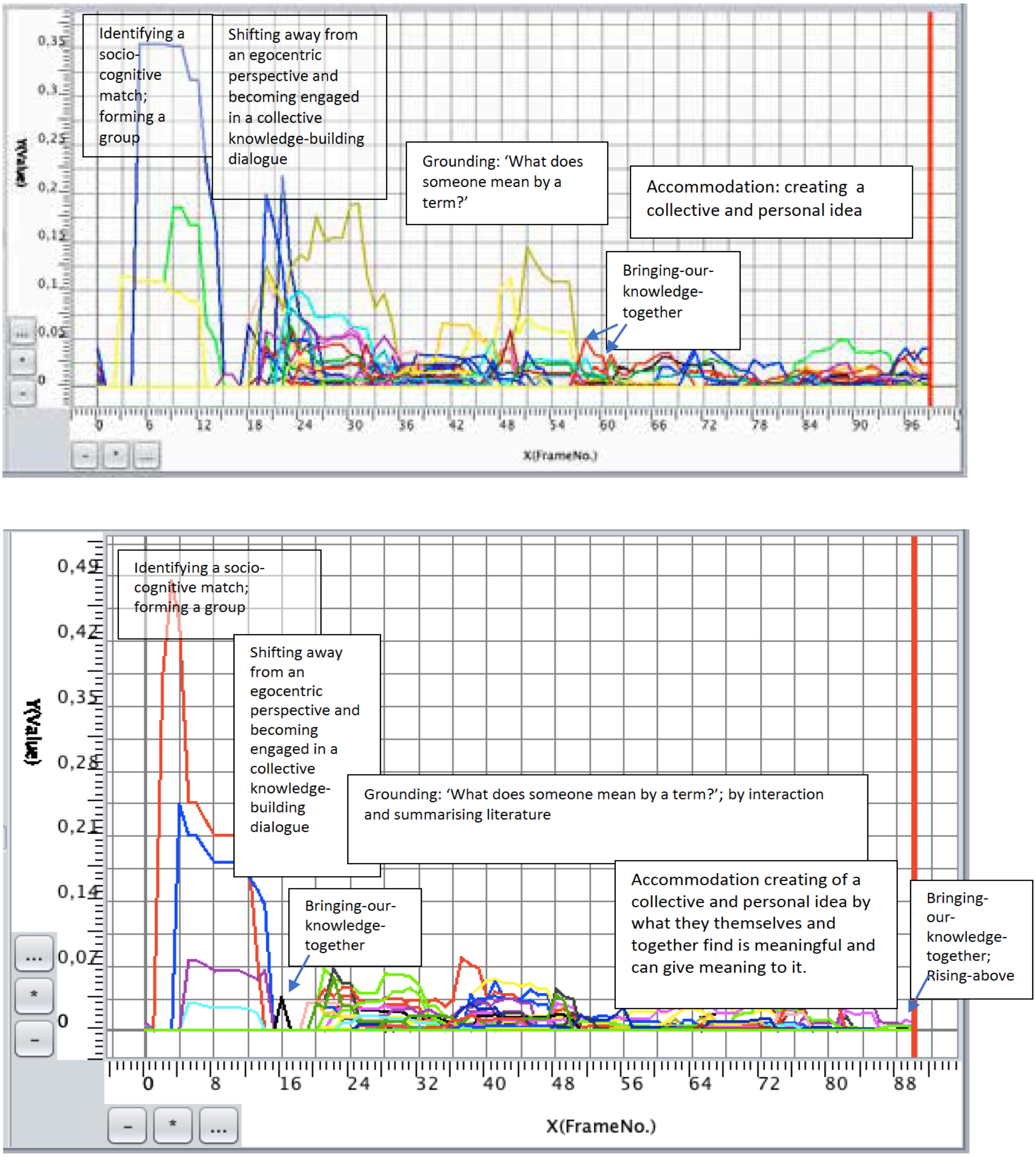

Figure 8: The between centrality and discourse activities on term level in the word network for group A (upper) and group B (lower).

Conclusions

The role that information of authoritative resources (i.e. topics, concepts, words that cover the topics in the literature (topic terms)) play in students' in-(ter)-action to develop their conceptual artifact is different in groups.

Certain number of topic terms have stronger relationships with each other than others in the knowledge construction or the development of the group vision on learning in the one or another knowledge building group. The lack of such topic terms in a dialogue can considerably disrupt knowledge construction because so many relationships (geodesic paths, "surveying paths") continue to other topic terms. In group B there is less centralization and there is a less coherent or looser relationship between a number of topic terms and topic terms have a more diffuse influence in the construction of the knowledge and / or vision that group B develops collectively.

The study reveals a nondominant nature of the actions in which those topic terms perform their connecting function during the discourse. The frequent changing of the connecting function over the topic term concept during the discourse means that the discourse is not dominated by one concept, but explorations and deepening of concepts take place in which different topic terms play a constructive connecting role.
Although, different topic terms have this connecting roles in the two knowledge building discourse groups same kind of patterns or discourse activities can be recognized in the knowledge construction process and is in line with the hypothesis and findings of De Jong (2015, 2019); Harashim (2017); Vogel & Weinberger (2019). We can identify different activity patterns in the knowledge-building process in which topic terms play an instrumental, connecting role:

1. *Group formation*: the collective knowledge-building process begins with an activity in which the insights 'acquired' by everyone are shared and a socio-cognitive content-based match is sought, giving rise to group forming through a sense of connection in relation to content.
2. *Collective engagement*: this is a process of moving away from one's own egocentric perspective and engaging in a collective knowledge-building dialogue. The purpose of reading information changes from seeking confirmation of one's own ideas to looking for what helps to find an answer to a collective question, testing promising collective ideas (theory), curiosity or solving a problem.
3. *Grounding*: a 'dialogue' about what exactly everyone means by seemingly clear terms in everyday use. Both groups did this by delving into the literature and discussing it with one another. It is a zone of non-resistance, where students come together, overcome their prejudices and recognize their interdependence in order to arrive at a shared transdisciplinary understanding (Brockwell, 2019).
4. *Integration and construction*: accommodation, creation of collective and therefore individual ideas by integrating and connecting ideas that rise above prior understanding; ultimately writing or creating a conceptual artefact.
5. The transition from one discourse activity to another appears to be supported by "bringing-our-knowledge-together" and 'rising-aboves. These are contributions in which students take stock and establish relationships between topic terms and their own idea at that time

In these knowledge building discourse activities, knowledge experiences (experiences in practice, studying literature, conversations, etc.) transform into images, concepts and ultimately into theoretical insights. The collective activity in the knowledge construction process of students is the engine of developing their new insights with emergent their 'conceptual artifact' as a reflection of their new way, psychological functioning, looking at the world and his / her responsiveness and relationship with others and their surroundings.

The educational learning process in knowledge building programs is based on active and collective exploration and understanding the deeper essences of issues. In addition, students acquire powerful conceptual skills to think critically, independently and yet collectively, to develop perspectives, and to develop insights and ideas that contribute to the design of ecologically responsible solutions. It helps students to develop their analytical, historical, linguistic and social thinking, and their epistemic skills in such a way that not only they become wiser, but also their environment. Knowledge building discourse is a talking together that has to be learned and be supported by teachers. The above rpeorted results helps us to understand the learning discourse. We don't have enough space in this article to go in detail about practical takeaways educators and teacher trainers might be able to use in their practice. However, De Jong (2019, 2020) is describing concrete activities for students, teacher, technology support in relation to knowledge building principles on base of above-mentioned activity phases in the knowledge building discourse.

The results are also a source for the reconceptualization of cognition as an internal information processing process into cognition as embedded in, present in, performed in the world and embodied in biology (Embedded in, Extended to, Enacted on to the world and Embodied in biology). Parada & Rossi (2018) see this reconceptualization as one of the frameworks that the development of psychological science needs to identify and study mechanisms that initiate outward-directed activities facilitated by ever-present neurological, inward-facing activities. These mechanisms do not concern the reductionist mechanistic if-then statements, but contemporary complex and dynamic learning mechanisms, focused on development and construction instead of "learning" as information processing.

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Knowledge Building as a Way of Life: Enculturating Students into World 3

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Abstract: Communities can be powerful drivers of learning and transformation. Knowledge Building communities aim to foster students' epistemic agency toward high levels of ownership over individual and collective learning – students come to enjoy relying on one another to advance their community knowledge. This case study examines pedagogical and technological designs for enculturating students into World 3, the world of ideas, theories, designs, and conceptual artifacts. From the first day of school, the teacher adopted a holistic approach toward principle-based designs, simultaneously engaging in multiple principles across multiple curricular areas. Furthermore, the process was catalyzed when she directly involved students in co-designing their Knowledge Building culture, including the norms of interaction, discourse structures, knowledge goals, and trajectory of knowledge advancement. Student and teacher reflections reinforce the notion that Knowledge Building is more than just an instructional framework: It is a philosophy – a way of living and being in contemporary knowledge societies.

Introduction

Communities can be powerful drivers of learning. In schools, learning communities have been designed to support: (1) development of diverse expertise among students, (2) advancement of shared goals, including knowledge and skills, (3) continual reflection on learning how to learn, and (4) mechanisms for sharing what is learned (Collins & Kapur, 2014). A growing body of research in the learning sciences demonstrates that learning communities deepen students' disciplinary understanding while promoting key competencies for working creatively with knowledge (Chan, 2013; Bielaczyc, Kapur, and Collins, 2013). Learning communities, thus, represent a promising approach to enculturate students into knowledge societies.

In a Knowledge Building community, the teacher finds ways to enable students to take on high levels of ownership over their learning from day one of school. One way to achieve this is through immersion into authentic knowledge work. In an effort to transform traditional participation structures, the Knowledge Building teacher encourages students to assume *collective responsibility* (Scardamalia, 2002) by intentionally de-centering herself from class discussions. Students come to rely on one another to sustain community knowledge advancement (e.g., Zhang et al., 2009; Ma et al., 2016; Ma & Akyea, 2020). Additionally, the teacher can shift traditional relations between students' ideas and experts' ideas, such as the curriculum, to bring students' ideas to the forefront of classroom interactions (e.g., Teo, 2014; Caswell & Bielaczyc, 2002; Toth & Ma, 2018). By making students' ideas the objects of inquiry for the community, students are enculturated into activities in World 3 (Bereiter, 2002) – the world of ideas, theories, conjectures, and design problems – and they learn to see themselves as *epistemic agents* responsible for improving conceptual artifacts, otherwise known as *real ideas and authentic problems* (Scardamalia & Bereiter, 2014). Students come to understand that community knowledge "lives 'in the world' and is available to be worked on and used by other people" (Scardamalia & Bereiter, 2003). A few of the Knowledge Building principles (Scardamalia, 2002) are discussed here, and concrete examples of all 12 will be detailed in this case study.

The design challenge for teachers is creating a holistic system of principle-based practices that facilitate self-organization around community knowledge advancement (Chen & Hong, 2016). Teachers new to Knowledge Building face the added challenge of unlearning practices that keep them at the center of discourse and assignments. Students must also unlearn the game of schooling, including the desire to look smart by contributing fake theories (Bielaczyc, 2018) and relying on the teacher to validate their ideas (Milinovich & Ma, 2018). While past studies (e.g., Zhang et al., 2009; Tarchi et al., 2013) indicate that it can take anywhere from a few months to a few years to foster a Knowledge Building culture in the classroom, recent work in the context of the Knowledge Building Innovation Network (Ma et al., 2019) in Ontario suggests that engaging educators in iterative design cycles of principle-based practices can support and even catalyze the development of teachers' efficacy in Knowledge Building.

In this paper, we elaborate on exploratory and iterative processes involved in designing a holistic system of principle-based practices in an elementary classroom. More specifically, we follow the journey of Emily Horner, a Knowledge Building teacher in Milton, Ontario dedicated to fostering a learning community that departs from traditional classroom practices so that students may see themselves as Knowledge Builders. Emily involved her students directly in co-design and re-design of classroom practices that facilitated community knowledge advancement. In each subsection, we provide an overview of Emily's design ideas before describing how she simultaneously implemented multiple principles into classroom practices that spanned across multiple curricular areas: science in the fall, social studies in the winter, and math in the spring. We conclude each subsection with excerpts of student discourse and teacher reflections on how Knowledge Building and Knowledge Forum have transformed their classroom experiences.

Co-Designing Norms and Practices for a Knowledge Building Community

Epistemic agency, Community knowledge, Democratizing knowledge, Knowledge Building discourse.

When Emily first started the school year, she was experimenting with different tools and strategies from the Knowledge Building Gallery (Resendes & Dobbie, 2017) to help students go deeper with their collaborative inquiries. Examples included planning with a big idea, looking for cross-curricular connections, and using "wonderwalls" to make student thinking visible.

a) b) c)

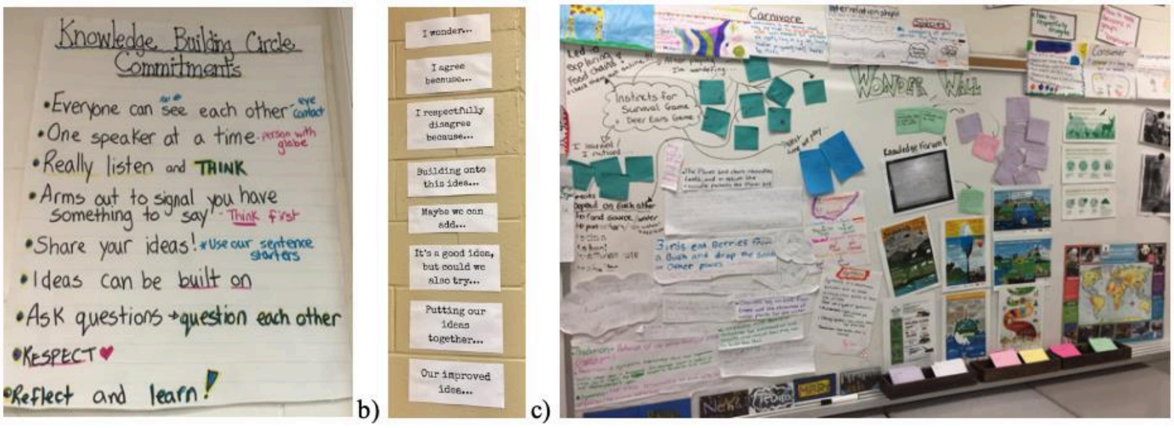


Figure 1. Knowledge Building a) circle commitments, b) scaffolds, and c) wall.

One of the first practices she tried was Knowledge Building circles, which at the time, she viewed as a place for students to share their learning. She also worked with her students to co-create commitments for Knowledge Building circles (Figure 1a) to help students understand that this was meant to be a safe space to share ideas and reflect on their learning together. Their commitments focused on how all ideas mattered, ideas can be improved upon, and how students (not the teacher) would choose who would speak next. This practice addressed the principles of *epistemic agency, democratizing knowledge, improvable ideas,* and *collective responsibility*.

Shortly after, Emily reflected on the quality of discourse happening in her classroom: "Were our conversations really leading us to deeper understandings?", "Were students truly listening to each other in a way that they actually thought about what each other was saying and how their own ideas fit or didn't fit with each other?", and most importantly, "Did they see the value in learning from each other or just from the teacher?". Guided by these questions, Emily redesigned the Knowledge Building circles to include the use of Knowledge Building scaffolds (Figure 1b) and noticed that students began to use them right away. As they moved along, they added in more scaffolds, such as "I used to think", "Now I think", to support metadiscourse, and she also encouraged students to co-create their own scaffolds. This shift in practice addressed the principles of *Knowledge Building discourse* and *embedded, transformative assessment* while maintaining the centrality of the previous principles.

From there, Emily also began to rethink the idea of "wonderwalls" by adding the Knowledge Building scaffolds in print as well. Based on an example in the Knowledge Building Gallery, she created little squares of paper with Knowledge Building scaffolds colour-coded to represent the different types of contributions. Students started writing their thoughts and posting them in a public space where they would refer to and work on over sustained periods of time. This shift in practice helped deepen the principles of *democratizing knowledge* and *community knowledge*. Figure 1c shows the Knowledge Building wall, which includes students' theories (green), questions (purple), artifacts (e.g., notes, observations, drawings, writings), *authoritative sources* (e.g., diagrams, maps, infographics), and a screenshot of their view in Knowledge Forum, which was introduced to the class in early fall.

Student Reflections

Students treated Knowledge Forum as an extension of their Knowledge Building wall and were excited to continue their work in a dynamic online space where their ideas could be organized flexibly and grow infinitely along with everyone else's ideas in a giant web. To Emily's surprise, students were so engaged with each other's ideas that they would log onto Knowledge Forum during evenings to continue discussions with their peers. Because their discussions were no longer confined to school hours, their Knowledge Building became *pervasive* and their community knowledge started taking on a life of its own. Using *embedded assessment* tools, such as the activity dashboard, Emily could see which students were taking initative to start conversations and which students were providing supportive roles by building on. Below are a few students' reflections on their experiences using Knowledge Forum.

> **Student A,B,C:** Knowledge Forum is a good resource for getting more ideas on a topic and seeing what other people have to say about your ideas and research… [It's] good for organizing a group of people's thoughts.
> **Student D**: Basically you paste your ideas on it… so the whole class has access to this and you can put in whatever idea you like.
> **Student E**: You add on to each other's knowledge and it keeps on going.
> **Student D**: For example… [if] you were wondering something you would have the sentence starter called "I wonder", and you could add on to that.
> **Student F**: Also another good thing about Knowledge Forum is that you can work/read people's ideas while being away/at home.

Teacher Reflections

Below are Emily's reflections about Knowledge Building circles and Knowledge Building scaffolds:

> I don't think I really recognized the power [the Knowledge Building circles] held… [until] I saw them as a collaborative space to work on and improve ideas… The Knowledge Building scaffolds [were] a real game changer for me. [They served as] starting points for some of my quieter students to enter into conversations and challenged some of the other students to go deeper. These scaffolds gave my students the power of language and they took over the direction of learning, as students' thinking moved to the forefront. It broke down some of the pressure I felt and my students felt because we learned we did not have to have the answer right away but that we were a community and we would help each other to work towards creating this knowledge – we were all co-learners, teacher included. This naturally led way to my own and my students' understanding of *community knowledge and collective responsibility*. We learned how to depend on each other to move our thinking. I started to rethink my role in a Knowledge Building circle and learn to wait and to let my students speak.

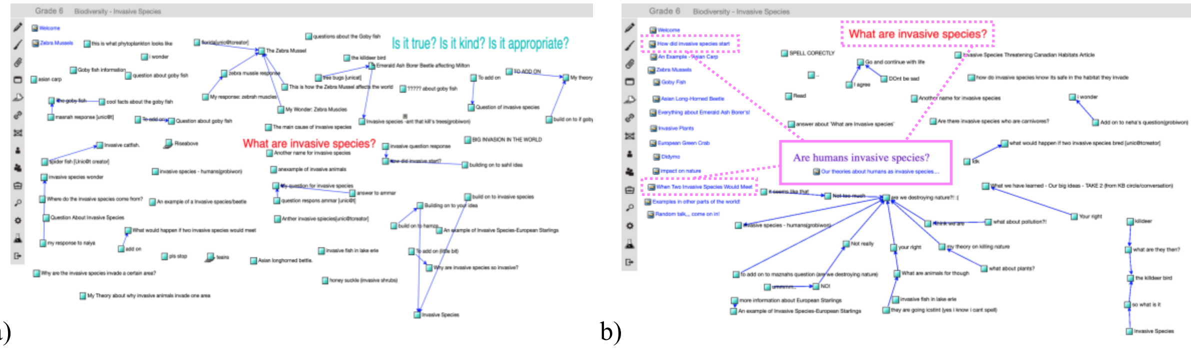
Below are Emily's reflections about Knowledge Forum:

> In a way, Knowledge Building walls and Knowledge Forum have become a tracker of our learning journey in a public space – one that we can interact with throughout the year. We can see our ideas and knowledge progress over time, further deprivatizing our learning. Knowledge Forum has provided a public space for my students to document the evolution of their ideas and learning journey, while visually being able to see and form deeper connections between ideas. Knowledge Forum also naturally taught my students digital citizenship, and it opened up many more opportunities in connecting with students at other schools, which really helps with *idea diversity* for the students. I loved how all my students felt they had a voice, even the quieter ones… [It gave everyone] multiple opportunities and platforms to speak, whether it's in a Knowledge Building circle, on a Knowledge Building wall, on Knowledge Forum, or even in reflection logs.

Knowledge Building/Knowledge Forum Designs in Science

Real ideas and authentic problems, Idea diversity, Improvable ideas, Rise above.

The first curricular area Emily tried with Knowledge Forum was science. After reviewing norms for digital citizenship (i.e., "Is it true?", "Is it kind?", "Is it appropriate?"), students were given full control to create and design their views in Knowledge Forum, thus furthering the principle of *epistemic agency*. Figure 2a shows the Knowledge Forum view where students shared initial theories about invasive species. The blue links on the left of Figure 2b show the different types of invasive species that students chose to research individually or in groups, such as zebra mussels, goby fish, Asian long-horned beetles, and other examples in other parts of the world (*idea diversity*). Students were also personally invested in learning about the Emerald Ash Borer, a beetle that “originated from Asia in China”, which humans “accidentally introduced to North America in imported wood packaging” and consequently “killed over 250 ash trees in Milton” (*real ideas, authentic problems*). As students conducted their research, they continued to advance overarching issues that they had identified would be relevant to their community knowledge, such as “How did invasive species start?”, “How do invasive species know it’s safe in the habitat they invade?”, “What would happen if two invasive species bred?”, and “Impact on nature”. Eventually, their discussions led to the *rise-above* question “Are humans invasive species?”.



a) b)

Figure 2. Knowledge Forum view on biodiversity a) at the beginning and b) at the end of their research.

Student Discourse

Below is an excerpt of the online discussion in Figure 2b). It can be seen that students were engaging in key scientific processes, such as theorizing, asking questions, and providing evidence to support their explanations. Of note, students were so deep in design mode with ideas that they did not settle on a quick yes-or-no answer to their rise-above question. Instead, they showed a willingness to explore alternative perspectives and discuss tensions that arose between humans and their environment, such as the need for using plants for shelter, tools, medicine, and research. One student even developed an analogy to highlight these complexities – a hallmark of design thinking (Bereiter & Scardamalia, 2003; Martin, 2009).

> **Student G**: An invasive species is a plant, fungus, or animal species that is not native to a specific location (an introduced species), and which has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health.
> **Student H**: [I wonder:] are humans considered invasive? We came from nowhere and destroyed the environment and killed thousands of species such as the thylacine (a hyena tiger mix) and the elephant bird.
> **Student I**: We really are destroying the wildlife. We cut down trees. We kill so many animals. We pluck out plants. Are WE the ones destroying nature?! :(
> **Student J**: [My theory:] is not really. We cut down trees to make things for us to survive. And some plants help sick people. It isn’t exactly the best thing to do, but doing this saves lots of people. We will continue to plant more plants though.
> **Student K**: Yes and no. Some people pick flowers for nothing but also, some people will do it for research. Some people cut down trees for no reason, but some people cut down trees to make peoples lives easier to make toothpicks, paper, chairs, doors, and so many more things that we use every day. So really, it’s not a yes or no question, it’s a both kind of question, like pizza or donuts – the answer is both! :D

Teacher Reflections

Below are Emily’s reflections about her evolving role in the Knowledge Building community as students began taking on increasing amounts of collective responsibility for idea improvement. As an alternative to giving students big questions to answer, Emily was finding promising questions that students had asked which had potential for sustaining discussions:

> I became more intentional about highlighting certain ideas expressed by students that would prompt more thinking, such as “Are we, are humans invasive species?”. When we highlighted this one idea, this led to so many more theories and questions being asked… I also focused on redirecting students’ ideas and questions to the group to help students form connections between what they were learning and to see how they could support each other in moving forward. This

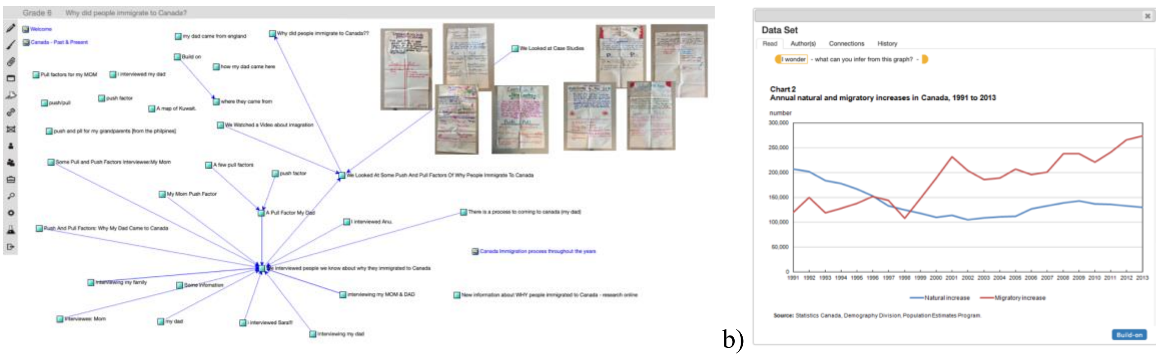
really helped my students feel comfortable in sharing ideas because they knew their ideas mattered. Not just to themselves or to me, their teacher, but to their peers. They started to depend more on each other across subjects, really believing “We’re not good until we’re all good”.

Knowledge Building/Knowledge Forum Designs in Social Studies

Real ideas and authentic problems, Constructive use of authoritative sources, Pervasive Knowledge Building.

As students became more proficient in using Knowledge Forum, Emily also began to rethink the way she introduced provocations and how she could design authentic tasks that really made students think. In particular, she was interested in understanding the *real ideas, authentic problems* her students wanted to solve or questions they wanted to unpack that lived within the curriculum. For her next design, she tried using Knowledge Forum in social studies, reframing the concepts of “invasion” and “migration” from ecological to societal contexts. Figure 3a shows the online discussion about “Why do people immigrate to Canada?” as part of the larger investigation into “Communities in Canada: Past and Present”, which also covered the history of colonization and legacy of residential schools in Canada, institutionalized sexism/racism, and cultural genocide (e.g., black slavery, WWII).

The Knowledge Forum view in Figure 3a contains notes with students’ theories, as well as artifacts from the classroom that documented students’ ideas about push and pull factors related to immigration. In line with previous designs which aimed to provide multiple entry points for students, students working in this view drew from multiple sources of information (*idea diversity*), including videos, case studies, and interviews with members of their community, such as parents, grandparents, siblings, and even one of their classmates. Collecting their own interview data made their investigation real and authentic. Moreover, having the opportunity to discuss the lived experiences with immigrants helped students develop a greater sense of empathy toward others, as well as a sense of appreciation for the rights and privileges they have as Canadian citizens. Students learned that Canada: is “wealthy and safe”, has a “really good health care system,… amazing services, lots of food, and no pollution”, offers “a better future in terms of education and job opportunities”, and overall, represents “a better place [for families] to live”. Additionally, Emily supplemented the discussion with an *authoritative source*, a graph from Statistics Canada, to help students get a birds-eye view on immigration trends in Canada.



a) b)

Figure 3. Knowledge Forum a) view on why people immigrate and b) note with data on immigration trends.

Student Discourse

Below is an excerpt of the online discussion about the graph on immigration trends as shown in Figure 3b. It can be seen that students were engaging in key mathematical processes, such as reading the legend, defining key concepts, identifying patterns (e.g., minimum, maximum, range, scale), analyzing the rate of change across the groups, as well as generating theories and predictions to explain their observations. Additionally, students who were co-authoring brought in different conceptions of “migration” from social studies and natural sciences perspectives, which further enriched their discussion. Their Knowledge Building was becoming increasingly *pervasive* as ideas cut across different curricular areas.

Student L,I,M: Migratory=red, Natural=blue. We say that the red rate was at its lowest in 1998 and blue was lowest in 2002. It was highest at 2013 in the whole graph.

Student N,J,OK: One way the population increases is Migratory which means people move to that area which is in this case Canada. The Annual Natural increase is for when babies are born. This graph compares the two topics and shows the increase and decrease. The range of this data is 160,000.

Student P,Q,K: The natural increase means the birth rate in countries. Migration means the migration of animals. Migration(Migratory) increases one year and decreases the next. The natural increase has decreased from 1991. The scale goes up by 50, 000.
Student E: We notice that the migratory went up and the natural went down. We think that the migratory increase will go higher in the years because if you look at the line graph, it went higher. Also, we think that the natural increase will go lower each year.

Teacher Reflections

Below are Emily's reflections about her evolving perspective on connections in the curriculum:

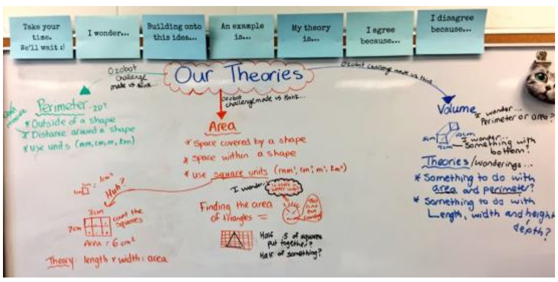
> Students have been uncovering the curriculum through their questions and wonderings and we can see the progression of their thinking over time. I have learned that I need to be intentional in planning provocations and highlighting students' promising ideas, but at the same time remain flexible in changing my plans as I respond to my students' curiosities. The connections students have made across subjects and beyond curriculum blow me away, and I can see them empowered as they build their knowledge together. Curriculum areas permeate into other curriculum areas, with students applying what they have learned in different situations, as well as highlighting new connections. I think this truly shows movement of ideas and that learning has taken place. Ultimately, learning is an iterative process. It's not just when the unit is done, this learning is done. It continues. Students think about how they are going to connect and move the knowledge forward for the next inquiry that they look into. I think this shows real growth in their views about knowledge and learning.

Knowledge Building/Knowledge Forum Designs in Math

Idea Improvement, Knowledge Building discourse, Symmetric knowledge advancement, Rise above.

Once Emily became more comfortable with Knowledge Building and Knowledge Forum, she started to reflect on how her teaching practices could be applied to mathematics: "How could she bring students' ideas to the center of math, as she had done in other curricular areas?". To tackle this problem of practice, she focused on provocations that had potential for students to create new knowledge about the concepts in the curriculum. Although she was initially nervous that encouraging students to generate theories and conjectures would uncover many misconceptions, she later realized that it was the misconceptions themselves that provided basis for investigations that led to *idea improvement* and deeper understandings of important mathematical concepts.

Figure 4a shows notes from a Knowledge Building circle about area, perimeter, and volume. It can be seen that the Knowledge Building scaffolds (in blue) were added to the top of the white board, which helped students engage in *Knowledge Building discourse* in math. Students co-designed additional scaffolds to use specifically in math, such as "Another strategy is", "Have you thought about", and "Maybe we could try".

a) 

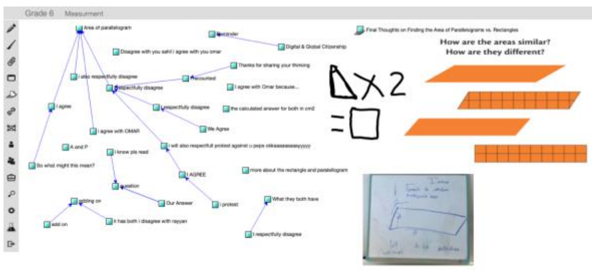
b) 

Figure 4. a) Knowledge Building wall and b) Knowledge Forum view on area and perimeter.

Student Discourse

Below is an excerpt of the online discussion about properties of rectangles and parallelograms, such as area and perimeter, as shown in Figure 4b. Similar to previous designs, Emily added a picture of student ideas from the whiteboard into Knowledge Forum to sustain discussions. It can be seen that students were engaging in key mathematical processes, such as classifying/decomposing shapes, counting metric units, calculating formulae, and reasoning spatially. A student even created a drawing to show how a square would decompose into two triangles.

Student R: They are both quadrilaterals… [with] two sets of parallel sides. The rectangle has all angles equal, while the parallelogram has opposite angles equal.

Student S: [My theory]: When looking at the picture, I noticed the 2 parallelograms and the rectangle both have the same area: $20cm^2$.

Student J,T: The length of the rectangle was 2cm and the width was 10cm long. The parallelogram also had the length of 2cm and the width of 10cm, so we did the formula for finding the perimeter (L + L + W + W), and both of the final perimeters were 24cm. For the area, since both of their lengths were 2cm and the width was 10cm, we just did the formula for area (L x W). We multiplied 10 x 2 and ended up with $20cm^2$.

Student F,V: We noticed that… The parallelogram has 4 half squares, add them together and it's 2 full squares! [My theory]: Our theory is that a parallelogram and a square could be classified in the same category.

Teacher Reflections

Emily noticed that students were as engaged in math as they were in science and social studies when they did Knowledge Building. Moroever, she saw that as students became more comfortable discussing strategies and math concepts (*democratizing knowledge*), they shifted their engagement toward gaining deeper understandings of math processes instead of rushing to get to the final solution. This inspired her to connect with another grade 6 class in order to provide new perspectives to students for *improvable ideas*. The two classes engaged in math and robotics problems and connected via online conversations in Knowledge Forum, followed by a virtual Knowledge Building circle on Google Hangouts which led to *rise-above* theories about the relations between speed, distance, and time. Students made connections across various strands in the math curriculum. Below are Emily's reflections:

> Overall, I have become a conscientious teacher, and I have learned with my students how to co-create ideas, work with them, improve on them… I have learned the power of co-teaching and co-planning. We teach math differently now. [Students are] focused on the bigger skills like communicating, expressing their ideas, being able to disagree with each other but then in order to move it forward, "Well I could solve it this way, have you thought about this?". It's about being able to listen to other perspectives and to be open about trying new things. One student reflected that, "Without using KF I wouldn't have known that – had I not had a place to read what other students discovered.". It was amazing to see the connections students were making to previous math knowledge, even more than we expected students to connect to and reflect on. Students also took time to help their peers who were not in their own group as they were excited to share their knowledge, and they truly exemplified what it means to be part of a community. My students are more curious, they think more about each other, and they feel more empowered.

Discussion

Knowledge Building aims to enculturate students into World 3 by the most direct means possible. This case study proposes that the process of enculturation can occur through an immersive co-design approach. From the first day of school, Emily empowered her students to design their Knowledge Building culture, which included the norms of interaction, discourse structures (i.e., scaffolds), and knowledge goals. Through co-design, they became Knowledge Builders advancing the frontiers of their community knowledge. When working in design mode, students came to learn that Knowledge Building was not just something they did in science, social studies, or math, but that their questions would continue traveling into different curricular areas, allowing them to criss-cross knowledge domains (Scardamalia & Bereiter, 2016). Additionally, Knowledge Building was not something they did in Knowledge Building circles or on Knowledge Forum – their physical and digital spaces became seamlessly integrated to facilitate the flow of ideas within and between classrooms. Their Knowledge Building was pervasive.

Past work suggests that teachers new to Knowledge Building commonly start with the principles of *real ideas, authentic problems; idea diversity*; and *Knowledge Building discourse*, then as they go deeper with their practices, they start addressing *community knowledge, collective responsibility; democratizing knowledge*; and *improvable ideas* (Ma et al., 2019). This case study reinforces the notion that the Knowledge Building principles are interrelated and work together as a system. While this is only one classroom example, it should be noted that Emily chose different principles than other new teachers in the Knowledge Building Innovation Network, which may explain how she led to deeper practices faster. One reason could be due to her design approach, which aimed for simultaneous and holistic integration of multiple principles. Another reason could be due to her choice of principles – ones that are drastically different from traditional schooling cultures (i.e., *epistemic agency, community knowledge, democratizing knowledge, Knowledge Building discourse, improvable ideas*). In a similar way, another Knowledge Building teacher in Ontario started with principles of *community knowledge, democratizing knowledge,* and *Knowledge Building discourse* which not only deepened student learning but also shifted their attitudes toward learning (Milinovich & Ma, 2018). We are not promoting a sequential or scripted approach to Knowledge Building, but we also do not rule out the possibility that some principles may be more effective than others at getting started with fostering a Knowledge Building culture. For example, starting with *constructive use of authoritative sources* may be challenging to bring student ideas to the center, however, this principle may prove to be useful when students are already dealing with *real ideas* and working *collectively* on *improving* them. The key takeaway here is that the teacher must engage students in co-design and re-design of emergent structures for ever-deepening inquiry processes (Zhang et al., 2018).

Communities can also be powerful drivers of change. Learning communities emphasize "learning to be" instead of "learning about" (Sawyer, 2006). Our case study illustrates that students can become Knowledge Builders by participating in iterative design with their teacher. This work has practical implications for an emergent line of research on the development of teacher identities (Vokatis & Zhang, 2016) and student identities (Hod & Ben-Zvi, 2018) in Knowledge Building communities. As Bereiter (2002) notes, "The knowledge building classroom… [re]presents a miniature of the knowledge society into which students are to become enculturated". We further that the mini knowledge society co-created by Emily and her students are not merely a reproduction of existing realities outside the classroom, but rather, a re-imagining of what life in a knowledge society can look like when all ideas are valued and all members are empowered to contribute equitably to the advancement of collective goals. For this to happen, Knowledge Building must be a way of life for the teacher as well as her students (Scardamalia & Bereiter, in press; Tan et al., 2016).

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Towards Capturing and Storytelling of the Evolution of Thought in Knowledge Building Communities

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Abstract: Sustained creative work with ideas is a key concept within the pedagogy of Knowledge Building as it is a fundamental means in which a community advances and deepens their understanding of a set of problems. Although creative ideas can be classified after they have been contributed, it is difficult to determine how they arose. Without understanding the seed of a creative thought and the path that led to its contribution in a community it is also a challenge to teach how to think creatively as required by various 21st Century competencies initiatives set forth by education ministries, particularly in the Ontario context. This conceptual paper seeks to describe the necessity for the capture and analysis of thought evolution as well as a potential model in which this could be achieved.

Introduction

A core ability essential to the 21st century is creativity or creative thinking, as determined by OECD (2001, 2018) and the Ontario Ministry of Education (2016). Creative thinking has several benefits at the personal, community and global levels. First, creativity allows individuals and groups to have a competitive edge over their peers due to the innovation that may arise (OECD, 2001). Second and more importantly, creativity is a social good (Banaji et al., 2010) that enhances a student's social and personal development.

Despite the obvious benefits and importance that creativity has for students, Lucas, Claxton and Spencer (2013) state the central challenge of creativity in education is that it does not *fit* in any subject, but spans across and can be cultivated, analyzed and assessed in a plethora of methods. This is challenge is further exasperated by access to easy-to-use software, hardware and social platforms that allows students to creatively apply their knowledge in any number of methods for any number of reasons, with then has an influence on their education. A promising means of enabling the cultivation of creativity is the use of Knowledge Building as a principled-based pedagogical approach elicit and capture sustained creative work on ideas. This is in part due to how Knowledge Building requires students to authentically and constantly move deeper in their understanding of a subject-domain in order to solve genuine problems. When faced with *wicked problems* (Rittel & Webber, 1973) creative thinking is perhaps the only means of arriving at a meaningful solution. As such this paper seeks to accomplish two main objectives:

1) Describe the need for the capture, analysis, and storytelling of student creative thought evolution
2) Propose means in which the evolution of creative thought can be captured

Background

To understand why we need to capture the evolution of creative thought it is essential we review the existing literature surrounding creativity, Knowledge Building as an enabler of 21st century competencies and digital stories as a vehicle for conveying thought. The following section will review these areas in some depth to provide context before proposing methods in which evolution of thought can be captured and analyzed.

Creativity in Education

Creativity is a difficult term to define and even harder to analyze, perhaps for the same reason why it is challenging to cultivate as an essential competency for the 21st century. Scholars have defined creativity in several manners ranging from the Four-C model by Kaufman and Beghetto (2009), the application of all knowledge to solve a particular problem (Weisberg, 1999), must be original and effective (Runco and Jaegar, 2012) and creativity as craft (Glaveanu, 2018) to name a few. Each of these definitions tries to capture a different perspective of what creativity is or should be thought of as.

For example, Kaufman and Beghetto's (2009) *Four-C* model breaks creativity into four segments that begin internally *(mini-c*), then moves externally at a personal level (*little-c*), then professional (*pro-c*) and finally global scale (*Big-C*). As you move along the spectrum creativity becomes more meaningful and influential to a wider range of people and requires arguably more skill in developing these creative solutions. Students, although unlikely to achieve the latter two stages of creativity still exhibit creative moments throughout their academic years before finally becoming a professional. As noted by Kaufman and Beghetto (2009), creativity is not always explicitly recognizable, and often occurs tacitly. When creative thinking is externalized it doesn't necessarily have a great impact, novelty or effectiveness as other scholars (Runco and Jaegar, 2012) describe creativity, but it still holds value for the individual and potentially their immediate community. This distinction is important as it opens up how we think about, analyze, and teach creativity. The personally meaningful creative thinking (*mini and little -c*) is a steppingstone for the development of the competency in students.

Whereas many scholars discuss creativity as an individual endeavour, Glaveanu (2018) argues for the notion of *creativity as craft*, in which creativity is likened to craftsmanship rather than innovation or artistic expression. This paradigm of creativity takes the middle road between creativity that novel and original and creativity as a means of problem-solving with the addition of *context*. He argues that creativity does not happen in a vacuum and is very much influenced by a community that surrounds an individual. Effectively building on Vygotsky's (1987) zone of proximal development by scaffolding the creative actions of each person through collaboration and the sharing of resources and experiences.

By combining the notion of *mini-c,* in which creativity starts from the "transformation or reorganization of incoming information and mental structures based on the individual's characteristics and existing knowledge" (Moran & John-Steiner, 2003, p. 63) and *creativity as craft*, we move closer to a means in which we can study creativity. Recognizing that all students can be creative, which is influenced by those around us, frees us to rethink how we could use pedagogy to aid students in developing necessary competencies essential for the 21st century. In particular, various studies (Astutik & Prahani, 2018; Lin, Chang, & Lin, 2016; Lin & Wu, 2016) have begun looking at the use of new media and technology to develop creativity in education. Astutik and Prahani (2018) studied collaborative creativity in physics simulations and recorded positives increases in student creativity. Lin, Chang and Lin (2016) found that the frequency of quality ideas rose dramatically. Finally, Lin and Wu (2016) found their students achieved higher levels of creative fluency, flexibility, uniqueness and elaboration. These studies further highlight the need to study creative thinking in manner that is community-based rather individualistic, and idea-centered instead of strictly an exercise in producing artifacts.

Knowledge Building, an enabler for 21st Century competencies development

If creative thinking is focused on the development of ideas within a community than it would be necessary to consider pedagogies that are centered on working with ideas. Knowledge Building as defined by Scardamalia and Bereiter (2003) is the production and continual improvement of ideas of value to a community. This is achieved in part by applying the twelve principles of Knowledge Building such as: *increased epistemic agency, pervasive knowledge building, real problems; authentic solutions* and *community knowledge; collective responsibility.* Through the application of these principles' students can develop important 21st century competencies such as collaboration, creativity, self-directed learning and problem solving. This is achieved by first giving students more *epistemic agency*, specifically changing the social structure of a class so that students have greater responsibility as individuals and as community to drive their own learning in the pursuit of genuine solutions. When students have agency, they are more motivated and engaged as their contributions have a direct impact on the success of the community, in other words they build up a *collective responsibility* towards each other and their shared goals.

According to Zhang, Scardamalia, Reeve and Messina (2009) *collective responsibility* occurs when factors are present: awareness of the contributions of others, complementary contributions and distributed engagement amongst community members. To achieve this state of responsibility, students' work on the development of the competencies of communication and collaboration, allowing them to begin acquiring a deeper understanding of their peers, the goals of the community, the problems that need to be solved and how to work with each other. Alongside having greater agency and responsibility, students also need to form groups in an emergent and opportunistic manner (Chen & Hong, 2016). How groups are formed can enhance or detract from how successful students are at working with each other, especially when they are trying to become more self-directed in their critical thinking, problem solving and creativity. When ad hoc groups are formed based on how to best solve a problem rather than arbitrary conditions related to classroom management then "creativity emerges from an interactional process that involves a social group of individuals engaged in complex, unpredictable interactions" (Zhang, Scardamalia, Reeve & Messina, 2009, p. 13). After solving one problem, students can form other groups that build on previous ideas, generate new ideas, or solve additional problems as the need arises. With the freedom to adjust the very structure of their work and form new groups surrounding a specific problem rather than conform to fixed rotations based on time and other-defined goals, students can take charge at increasingly high levels. They can work with a variety of students with different epistemologies, increasing both the collective knowledge of the group and their individual knowledge as well.

In closing, Knowledge Building when applied to classrooms increases the agency of students and fosters greater collective responsibility in iterative idea improvement of community knowledge. Increased responsibility leads to deeper learning for the individuals within a community who share a desire to solve real problems. In turn, creative capacity is also increased through the improvement of personal and public spheres of knowledge while contributing to the solution of a complex problem. Sustained creativity and its application in a variety of situations are constantly tested as new knowledge is built. Ad hoc group formation with like-minded students further breeds an environment that allows for creativity to emerge as students make their tacit knowledge explicit (Nonaka, 1991; Orthel, 2015). Knowledge Building becomes a framework that aligns and promotes many of the necessary ingredients required for creativity to flourish and for the development of key 21st century competencies.

Digital Stories as vehicles to convey creative thought

Digital storytelling (DS) first grew out of a community arts movement during the 1980s in Berkeley, California (Lambert, 2013). DS typically are short narrative videos that combine images, audio, and text to create a video that has a personal significance. Since the introduction of DS, it has been steadily incorporated into the field of education and transformed into Educational Digital Storytelling (EDS). EDS has been applied in numerous ways and elicited a variety of benefits for students. Wu and Chen (2020) in reviewing EDS found five common methods for applying the practice across subject domains: *appropriative, agentive, reflective, reconstructive,* and *reflexive*.

Appropriative DS focuses on students gaining subject knowledge understanding through the construction of stories. Agentive applications look at providing students with greater levels of agency in their stories, such as choosing their own themes, topic of investigation, and so on. Reflective, provides students the space to contemplate new knowledge they have learned in relation to what they already know. Reconstructive DS requires students to breakdown and rebuild their understanding of a subject, engaging students in critical thinking and reconstruction of existing knowledge so they may build new knowledge. Lastly, there is reflexive DS which asks students to focus on themselves and develop a better understanding of their own identity, their worldview, and who they want to become.

Of the various EDS methods, *reconstructive* bears the closest resemblance to Knowledge Building as it asks students to critically question what they have learned and propose potential new breakthroughs to existing knowledge. When reconstructive EDS occurs as a community rather than individually there is potential for it to be a transformative practice that pushes the boundaries of a communities understanding of boundaries they may face and develop authentic solutions. EDS can be applied as a vehicle that aids students in Knowledge Building whilst producing digital artifacts that can be utilized as central points of discussion, markers of new inquiry directions, or higher-order summaries of community discussions. All of these can serve as a means of sustaining creative work with ideas as students enter a cycle of engaging, producing and sharing ideas.

Alongside the proper implementation of EDS to aid in building knowledge, digital stories have also been shown by scholars to motivate, engage and aid students in developing their creative thinking. While investigating how digital stories could enable collaborative creativity, Schmoelz (2018) found that the production of digital stories let students experience *co-creative flow.* When this flow is achieved students seek no specific reward or reason but to simply enjoy and immerse themselves in the action of being creative. Sadik (2008) found that when students presented their stories, they did not just report facts but actively engaged with the material and highlighted their own experience and perspectives in relation to what they learned. Van Gils (2005) noted that DS was motivational as it was easier for students to convey their exact thoughts regarding a specific topic as they had the affordance of multiple mediums of expression. In addition, they learned a new method of utilizing technology to tell personal stories that did not require specialized knowledge in production.

To conclude, EDS is a practical means of applying creativity thinking while enabling a range of other 21st century competency development. It also has the potential to elicit a state of flow for students that causes them to actively create and engage with the project without thinking about the goal but so they can create something for their enjoyment. Finally, if shared digital stories become artifacts that can spark discussions, further investigations, and even act as markers of an individual's learning progress.

Discussions

As described in detail, creativity is a difficult concept to define which makes it also a challenge to cultivate in students as there are a plethora of methods that could be used without any guarantee they would work. As such, it is crucial to capture evolution of thought with a specific focus on creative thinking so that researchers, teachers and even students themselves can gain an insight into how thinking changes overtime. An additional challenge of capturing the evolution of thought is if the thoughts occur in an ad hoc manner without a specific focus, such as when students are answering questions. What is required is a framework that elicits sustained effort by students to solve real problems that require authentic solutions. Knowledge Building pedagogy is a very promising means of achieving sustained work with ideas as it has repeatedly shown over the course of its history within education (Chen & Hong, 2016). In addition, Knowledge Forum, the companion web application, is often used as the primary means of applying the pedagogy. Being a digital platform, it inherently collects idea contributions which can be analyzed in the future, however there is potential to expand on the functionality or even norms of engagement related to use of Knowledge Forum so that a wider range of ideas can be captured and inputted.

First, as noted in the Huang's prior studies (2017, 2020) into the integration of mobile learning and digital storytelling into Knowledge Building, students are inclined and require the use of multiple mediums to contribute their ideas. Not only does it expand the range of ideas they could contribute, it also highlights the depth of their understanding that text-only would not be sufficient in conveying. Also, more prominent and easier to use means of contributing via multiple mediums increases the accessibility for students who may be struggling with one form of contributing or another. With multiple mediums, students have multiple points of entry into a discussion that ultimately can lead to them achieving *co-creative flow* which in turn enriches the community experience as a whole. One quick means of accomplishing this state would be to integrate digital storytelling practice into Knowledge Building so that it becomes a scaffold rather than an addition. In this way students are able to contribute a spectrum of media and ideas without hinderance, making building knowledge the most important goal. Furthermore, as students are drawn toward (Huang, 2020) personal stories it creates a natural hook that draws other students in to engage with the ideas contributed. In time, with shifts to both the norms of engagement in Knowledge Forum and the functionality, there is a hope that students will be highly engaged and motivated to spend time building knowledge well beyond the time set within class.

Second, if there is a wider range of media being contributed that enriches a community discussion, one can imagine a plethora of notes being generated that progresses steadily toward a verity of tangential solutions for community-specific problems. Although these are collected within Knowledge Forum, it does not make it easy to understand the evolution of creative thought or even analyze it for that matter, especially as sustained Knowledge Building spans months of work. A promising solution that can be applied, which is borrowed from filmmaking and photography, time-lapsing a community's work. A time-lapse in the traditional sense is a capturing the evolution of a lengthy process and shrinking the temporal plane so that the end result is a short form video. This is often used to denote the passing of time, or to study incremental yet minute changes in things. A common example is the use of time-lapses to film the blooming of flowers or a day-to-night transition. By time-lapsing a communities work we are now able to both view the entire transformation of solutions and ideas from start to finish, but also pick out particular points in time in which there was a significant shift in focus or even points in which a community began to diverge. This would be highly beneficial in getting to the root of creative thought evolution as one is able to both see the end result and the catalyst that started everything.

Lastly, introducing digital storytelling practice and capturing of thought evolution into Knowledge Building does not automatically result in understanding how individuals and community ideas evolve overtime. At this point these two concepts are separate, the former being used to potentially stimulate and sustain creative work with ideas, while the second just captures and plays back all the work done. A missing piece is the narrative of the community's evolution as told by individuals within the community. As an addition, it would be crucial and valuable to allow community members access to their time-lapses so they can use it tell a personal story about their Knowledge Building journey. This of course can be done in a digital storytelling manner, which in turn can be re-contributed into the community for further discussions. To further explain how these concepts could work together to allow us to capture and tell the story of the evolution of thought, I have included a conceptual model (see Figure 1).

Figure 1: Conceptual Model for Capturing the Evolution of Thought

A potential method of capturing the evolution of thought as proposed by Figure 1 is to situate Knowledge Building and Knowledge Forum at the center. Students contribute via multimedia based on their preference or what makes the most sense in a given learning situation, allowing them various avenues of expression that more closely aligns with their understanding. In this way, the hope is that authenticity of their ideas is maintained with minimal friction caused by forced translation from thought to a medium that does not connect with them. Lastly the outer circle is a constant capture of their ideas, which builds on the *Timemachine* functionality in Knowledge Forum, with the addition of allowing the students to annotate and generate stories of both community and individual evolution of thought. These stories provide an additional layer of context, guidance for others new to the community and most importantly are artifacts that can lead to even deeper levels of idea improvement.

Conclusion

Creative thinking is a necessary and crucial ability that needs to be developed by students as it is highly beneficial for their future careers within a knowledge society. The challenge lies within both describing what creativity is, how to cultivate it, how to study it and how to evaluate it. This paper is proposing a new conceptual model in which digital storytelling practices are used to elicit dynamic content creation by students that can be inputted into a shared Knowledge Building community space for further development into genuine solutions. In doing so, students are given a high degree of agency to contribute in multiple ways so that their authenticity is maintained. Furthermore, by capturing inputted ideas through a time-lapse manner, one is better able to analyze the progression of change made by a community, which can lead to a deeper and clearer understanding of how individual and community thought evolves. As this is only a conceptual paper, the logical next step is to apply it in practice with a smaller community that is inclined to explore the uses of digital storytelling within education. In this manner potential benefits and drawbacks to the model can be iterated on and refined for application with the same or larger community.

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Enhancing Inquiry-Based Learning in the Social Studies Classroom using Knowledge Building Pedagogy and Technology

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Abstract: This study examined the use Knowledge Building (KB) approach and Knowledge Forum (KF) technology to drive Inquiry-Based Learning in Upper Secondary Social Studies (SS) lessons. Lessons were designed based on KB's principle that allowed students to play a leading role in the construction of a core knowledge (Socio-Economic Status as a factor in shaping one's identity) and in the discourse on a related societal issue (identifying one way to help those who struggles to have their basic needs met) through active negotiation, dialogue and appropriate scaffolding with each other and with their teacher on the KF platform. We analysed the impact of the KB approach by examining students' final theories and explanations in terms of the levels of response and thinking. Results suggest that the KB approach, despite the constrain of time, provided an excellent platform for students to collaborate with each other and dialogue with their teacher in correcting misconceptions, in ideas development and make improvements on constructing explanations. Future considerations in the integrative use of KB and its technological affordances are required that can further develop students' ability to construct explanations that qualify as high levels of response based on a standard SS Level of Response Mark Scheme (LORMS).

Introduction

The revised Upper Secondary Social Studies (SS) syllabus highlighted that engaging students in discourse on societal issue is a complicated task and made the recommendation of using Inquiry-Based Learning (IBL) pedagogy to actively engage students in knowledge construction and meaningful learning through the Inquiry Process (MOE, 2016). The SS Inquiry Process can be described via four elements – mainly Sparking Curiosity, Gathering Data, Exercising Reasoning and Reflective. Figure 1 shows how the Inquiry Process looks like in the Social Studies classroom:

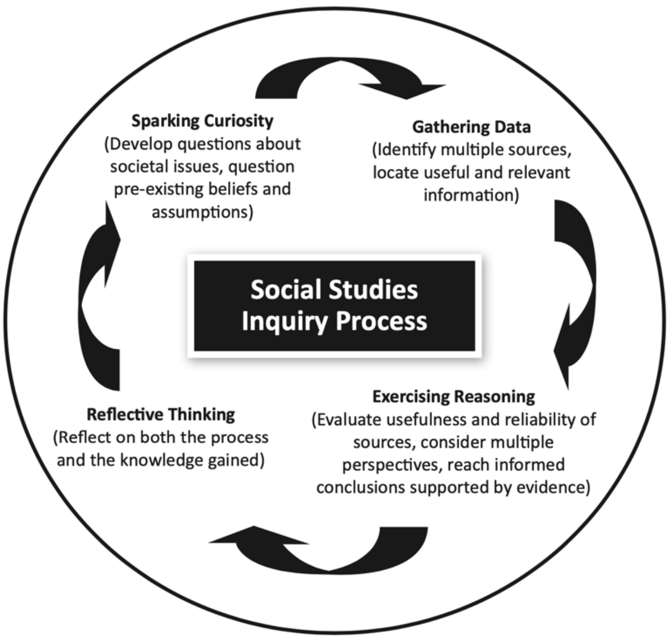

Figure 1: Social Studies Inquiry Process (MOE, 2016)

The premise that IBL results in significant learning as compared to traditional didactic instructional approach is evident, provided that appropriate scaffolding are in place for the learners (Hmelo-Silver, Duncan, & Chinn, 2007). An important element that drives effective IBL environments is the quality interaction and relationship between the instructor (teacher) and the learner, as well as between learners (Blessinger & Carfora, 2014).

The Knowledge Building (KB) approach postulates that authentic creative knowledge work can take place in school classrooms (Scardamalia & Bereiter, 2014). A key KB pedagogical principle – Improvable Ideas, entails that "every idea is to be treated as potentially improvable." Scardamalia and Bereiter (2014) believes that while the initial generation of knowledge, ideas and theories do come naturally to young people, the process of improving them does not. Considerable help from the teacher, technology and peers are required to maintain students' engagement in idea improvement. In technology, the Knowledge Forum (KF) is an online collaborative platform that supports KB Discourse (Scardamalia, 2017). The platform allows students to contribute ideas towards inquiry and offers scaffolding tools that enables negotiation, dialogue and appropriate scaffolding to take place between learners and the teacher in the Inquiry Process. In this study, we examine how a Social Studies teacher uses the KB approach, through KF, to enact effective IBL in the Upper Secondary Social Studies classroom.

Knowledge Building in the Social Studies Classroom

In finding out about students' perceptions on Social Studies in the American context, students found the subject to be boring when the teaching method was primarily an expository form of instruction (Chiodo & Byford, 2004). Moreover, the study also found that the perceived lack of utilitarian value contributed further to students' negative perception of the subject. For the latter, it seemed that the mere transmission of facts and ideas from the textbook rather than active involvement of learners in constructing knowledge was a key contributing factor. Furthermore, advancement of understanding on these societal "ideas", like the concept of Globalisation, come not so much as flashes of insight (or "a-ha!" moments), that inquiry on scientific theories provide, but only as increments of perceived complexity (Scardamalia & Bereiter, 2012).

Therefore, it is vital to apply the KB principle of Real Ideas, Authentic Problems when designing the Social Studies lessons. Authentic Problems, as Scardamalia (2002) puts, are problems that students care about and are very different from textbook problems. Authentic inquiry in Social Studies means building theories that explains particular cases, or Authentic Problems related to societal issues, which all the more makes KB a good alternative to accommodate both the interests of learners and the desired education outcomes of Social Studies (Scardamalia & Bereiter, 2012).

The classroom and teacher's lesson design

The teacher has 5 years of teaching experience and started adopting KB in his lessons in semester two, 2018. In semester two 2019 (runs from the month of July to November), the teacher went further by integrating KF in his KB class. The participants (*N* = 27) from this study were from one secondary 3 (grade 9) class in a government-aided school. The participants consisted of 15 females and 12 males. Of these 27 participants, 13 were Chinese, 7 were Malay, 4 were Indian and 3 were of other race or nationality. The class is an express class and considered the less academically inclined of their express cohort. Upper Secondary Social Studies is a compulsory subject for all secondary school students and, despite having exposure of the subject in their primary school years, the concepts taught can be considered new and unfamiliar to the students.

In selecting the Social Studies concepts with the principle of Real Ideas, Authentic Problems, the teacher chose the concepts of identity and socio-economic status (SES) found in chapter 4 of the SS textbook. The very concepts chosen are real and relevant to the students, especially so since they are all living in a multi-cultural and diverse society like Singapore. It is important to help students recognise that SES is a crucial attribute in shaping one's identity and, in turn, contribute to the diversity of Singapore.

In designing the lessons, the teacher incorporated KB principles[1], Elements of Social Studies and Pedagogical Practices postulated by the Singapore Teaching Practice. In considering the Pedagogical Practices, teachers can consider the teaching areas of the four core teaching processes that can help provide additional guide to lesson designs (MOE, 2018). Figure 2 shows the core teaching processes and teaching areas of The Singapore Teaching Practice Pedagogical Practices.

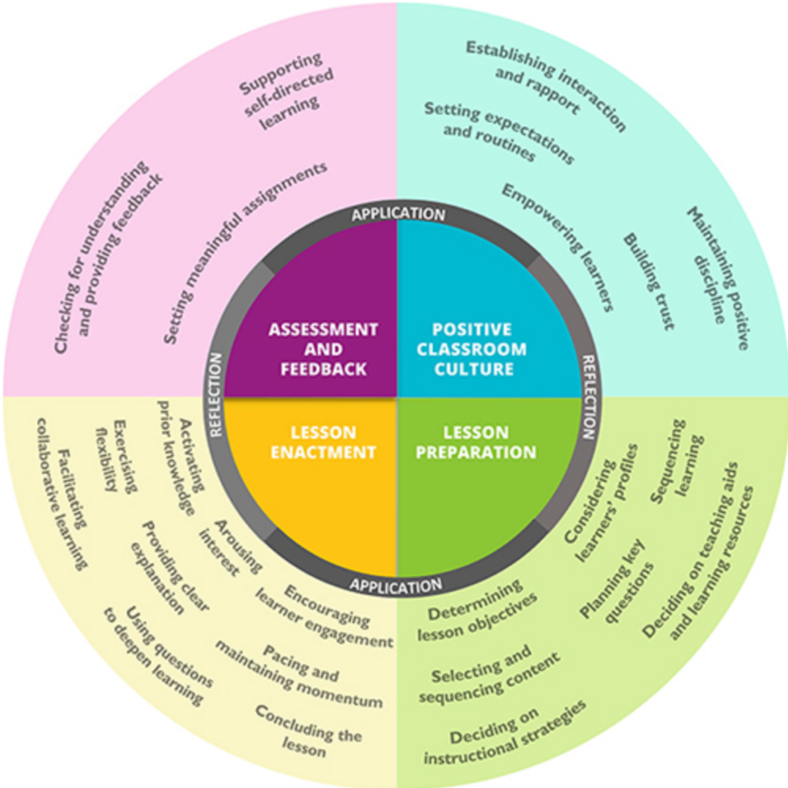

Figure 2: The Singapore Teaching Practice Pedagogical Practices (MOE, 2018).

The lesson design is broken down to three stages of inquiry. In enacting effective IBL through the KB approach, each stage corresponds to one or two elements of the Social Studies and areas of Pedagogical Practices. Tables 1a, 1b and 1c provide the framework and rationales considered in designing stage 1, stage 2 and stage 3 inquiry respectively.

Overall, students would play a leading role of not just contributing ideas to inquiry, but also take an active role, through collaboration, in improving ideas with the use of the scaffolding tools on the KF platform, driving KB discourse. This what makes KB an excellent approach to adopt in the Social Studies classroom.

Table 1a: Framework of Stage 1 Inquiry and teacher's rationales behind the design

	Stage 1 Inquiry: ***How would you describe your identity?***		
KB Principles	*"Real Ideas, Authentic Problems"; "Improvable Ideas"; "Idea Diversity"; "Democratising Knowledge"; "Community Knowledge"*		
Elements of Social Studies Inquiry Process	*Sparking Curiosity*	*Gathering Data and Exercising Reasoning*	*Reflective Thinking*
Areas of Pedagogical Practices (Based on Singapore Teaching Practice)	*Activating Prior Knowledge;* *Arousing Interest;* *Encouraging Learner Engagement.*	*Using Questions to Deepen Learning;* *Checking for Understanding and Providing Feedback.*	*Concluding the lesson.*
KB activities designed by the teacher	Students are tasked to provide response to the inquiry with the use of *My Theory* KF Scaffold.	Teacher to use KF Word Cloud Analysis Tool to check for students' understanding of their concept of Identity. Use questions to help deepen learning and see connections between their personalised ideas and the attributes that shape one's Identity.	Teacher concludes the lesson by introducing the core concept of SES. This lesson would spark off the reflective thinking process in the topic during the next stages.
Rationale for KB activities & Pedagogical Practices	Getting students to contribute towards their understanding of identity through contribution of personalised, real ideas. This part of inquiry can help to activate students' prior understanding of real-world issues and pre-existing beliefs (MOE, 2016) Brings about a culture of "democratising of knowledge" as all students are contributors of knowledge; this increases students' ownership, interests and engagement.	Allows students to appreciate diverse ideas from a community and understand the benefits of combining ideas to reach for better understanding and ideas development. Understands students' prior knowledge and/or misconceptions related to the Concept of Identity.	The process gets student to reflect on personal assumptions and beliefs that may have shaped their understanding on the concept of identity Provides the link to stage 2 inquiry.
Advantage(s) and Rationale(s) of Knowledge Forum	Provide a collaborative platform for students to see the variety of ideas at a glance and allowing students to see connections between the ideas through the Analytical Word Cloud Tool.		

Table 1b: Framework of Stage 2 Inquiry and teacher's rationales behind the design

	Stage 2 Inquiry: ***What is Socio-Economic Status?***		
KB Principles	*"Real Ideas, Authentic Problems"; "Improvable Ideas"; "Idea Diversity"; "Democratising Knowledge"; "Epistemic Agency"; "Knowledge Building Discourse"*		
Elements of Social Studies Inquiry Process	*Sparking Curiosity*	*Gathering Data and Exercising Reasoning*	*Reflective Thinking*
Areas of Pedagogical Practices (Based on Singapore Teaching Practice)	*Activating Prior Knowledge;* *Arousing Interest;* *Encouraging Learner Engagement.*	*Facilitate Collaborative Learning;* *Checking for Understanding and Providing Feedback;* *Encouraging Learner Engagement.*	*Checking for Understanding and Providing Feedback;* *Providing Clear Explanation;* *Concluding the lesson;* *Setting Meaningful Assignments.*
KB activities designed by the teacher	Students are tasked to provide response to the inquiry with the use of *My Theory* (KF Scaffold).	Students, in pairs, review each other initial theory and ideas on SES and provide comments using KB Scaffolds. The comments can be questions, suggestions or areas for improvement. Based on comments, students synthesise information to formulate a *Better Theory* (KF Scaffold) to the inquiry.	Teacher reviews lesson by displaying the formulated better theories to consolidate learning. Teacher uses students' better theories to explain the concept of SES. Based on acquired knowledge, students are tasked to read an article "*How to tell if Singapore is high or low class? Poll gets interesting replies from Singaporeans*"[2] and share their reflections and thoughts about SES on KF.
Rationale for KB activities & Pedagogical Practices	Getting students to contribute towards their understanding of SES through contribution of personalised, real ideas. Understands students' prior knowledge and/or misconception related to SES. Brings about a culture of "democratising of knowledge" as all students are contributors of knowledge; this increases students' ownership, interests and engagement.	Entire process is student-centric; Students takes a leading role in the scaffolding process and KB discourse. (Epistemic Agency) Brings about a culture of collaboration to "build-on" rather than "answering". Strengthens students' meta-cognition through evaluating, reconciliation of questions, suggestions and/or ideas to the issue. Supports assessment as learning through the culture of cross-referencing. Helps students appreciate that Social Studies Concepts are social constructs and discourse involves dialogue and negotiation. (KB Discourse)	Allows students to appreciate diverse ideas towards the concept of SES. Conclusion to consolidate learning of the concept. The reflection task provides students with an authentic view of how SES shapes one's identity in Singapore.
Advantage(s) and Rationale(s) of Knowledge Forum	Supports students' meta-cognition reasoning through its KB scaffolds of *"I need to understand", "This theory does not explain"* and *"I have new information"*. Provides a collaborative platform for students to see the variety of ideas at a glance and allowing students to see connections between the ideas. Provides an authentic learning environment to facilitate Social Studies discourse.		

Table 1c: Framework of Stage 3 Inquiry and teacher's rationales behind the design

Stage 3 Inquiry: ***"How can we help those who struggles to have their basic needs met? Explain your answer using one way"***			
KB Principles	*"Real Ideas, Authentic Problems"; "Improvable Ideas"; "Idea Diversity"; "Democratising Knowledge" "Knowledge Building Discourse"; "Rise Above"*		
Elements of Social Studies Inquiry Process	*Sparking Curiosity*	*Gathering Data and Exercising Reasoning*	*Reflective Thinking*
Areas of Pedagogical Practices (Based on Singapore Teaching Practice)	*Activating Prior Knowledge;* *Arousing Interest;* *Encouraging Learner Engagement.* *Setting Meaningful Assignments.*	*Checking for Understanding and Providing Feedback;* *Encouraging Learner Engagement.*	*Checking for Understanding and Providing Feedback;* *Providing Clear Explanation;* *Concluding the lesson.*
KB activities designed by the teacher	Pre-activity: The teacher shows the class an episode to a Channel New Asia documentary video titled "Don't call us poor".[3] After watching the video, students are tasked to provide response to the inquiry with the use of *My Theory* (KF Scaffold).	Teacher reviews each other initial theory and ideas and provides comments using KB Scaffolds. The comments can be questions, suggestions or areas for improvement. Based on comments, students synthesise information to formulate a *Better Theory* (KF Scaffold) to the inquiry.	Teacher reviews lesson by displaying the formulated better theories to consolidate learning. Teacher uses students' better theories to explain how to construct explanations. Teacher concludes that moving beyond knowing the definition of SES is the ability to apply knowledge gained towards analysing and resolving societal issues related to SES.
Rationale for KB activities & Pedagogical Practices	Rationale for watching the video: to enact on the KB principle of "Real ideas, authentic problems", it was imperative, as also highlighted in the SS syllabus, that the teacher facilitate the lesson by nurturing disposition that would let students demonstrate empathy in dealing with societal issues. Empathy as an emotion helps to enhance perspective-thinking and critical thinking skills (Gallo, 1989). Further research had shown that videos are effective as a platform to present authentic problems that improve students' satisfaction and empathy (Hee & Yang, 2011) and this would help students cultivate the skills required for stage 3 and KB discourse. Brings about a culture of "democratising of knowledge" as all students are contributors of knowledge; this increases students' ownership, interests and engagement. Stage 3 is also aligned to the scheme of National Assessment where students are required to apply their knowledge and construct explanations in answering Structured-Response Questions (SRQ) part (a).	Supports assessment of learning through teacher's identification of misconceptions/areas for improvement that students can use to re-evaluate their initial theory. Strengthens students' meta-cognition through evaluating, reconciliation of questions, suggestions and/or ideas to the issue. Helps students appreciate that Social Studies Concepts are social constructs and discourse involves dialogue and negotiation.	Allows students to appreciate diverse ideas to recommendations in helping those in need. *Rise Above*: Moving beyond definitions to higher planes of understanding in analysing societal issues. Conclusion to consolidate learning in analysing societal issues and constructing explanations. Entire inquiry process is a form of reflection for students where they reflect on the possibility of further actions and / or recommendations to an authentic problem. This prepares students in constructing explanations for SRQ part (a).
Advantage(s) and Rationale(s) of Knowledge Forum	Supports students' meta-cognition reasoning through its KB scaffolds of *"I need to understand", "This theory does not explain"* and *"I have new information"*. Provides a collaborative platform for students to see the variety of ideas at a glance and allowing students to see connections between the ideas. Provides an authentic learning environment to facilitate Social Studies discourse.		

Analysis of Stage 1 Inquiry (How would you describe your identity?)

In the first stage, students are tasked to describe their identity by inputting their responses on KF. Below are two samples of students' descriptions of their identities:

Sample one with the use of "*My Theory*" scaffold:

My theory: "I am a Philippine national citizen and residing in Singapore. I believe in Christ and is a fairly strong believer. My family doesn't even live in my country anymore. People think I look Malay or Chinese and sound English. I liked American shows when I was younger and thus the accent."

Similar, another sample with the use of "*My Theory*" scaffold:

My theory: "I am a girl.
I am a Muslim.
I am a Manchester united fan.
I am a Singaporean.
I am a Disney lover.
I am a cat owner.
I am a hockey player.
I am a cat lover.
I am a human.
I am Malay.
I am a daughter.
I am a sister.
I am a friend.
I am a student of tw."

After students input their responses, the teacher used the word cloud analytic tool in consolidating and displaying their ideas (See figure 3).

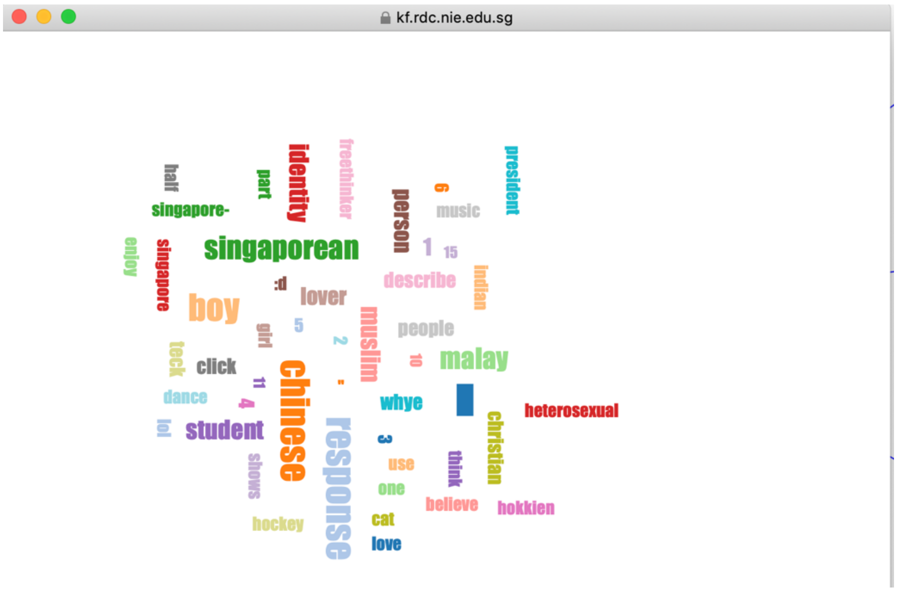

Figure 3: Word Cloud analysis of students' responses in describing their identity.

With the KB principles of Idea Diversity and Democratising Knowledge, the word cloud tool helped illustrate clearly the diversity of ideas, contributed by all students, pertaining to the concept of identity. Straightaway, students were able to categorised the words to the common attributes of nationality, race, religion, gender and personal interests as attributes shaping their identities. Based on the analytical word cloud tool, ideas related to SES are clearly absent. To deepen learning, the teacher tasked students to refer to their SS textbook and identify the "missing" attribute. In application of the KB principle Constructive Use of Authoritative Sources, the textbook became the avenue for students to fill in the missing gaps of knowledge and concepts. This formed the basis for the next stage as students became to recognise that SES is also an important attribute that shapes one's identity.

Findings of Stage 1 Inquiry

The use of the KF Analytical Word Cloud tool is evident on how the "democratisation of knowledge" can help the teacher understand students' prior knowledge and correct misconceptions of a concept. Overall, IBL is enhanced when the variety of ideas helped surface out misconceptions and / or led to the introduction of new theories and ideas.

Analysis of Stage 2 Inquiry (What is Socio-Economic Status?)

In the second stage, the teacher build-on from the introduction of SES in stage 1 and facilitated a classroom discussion on SES through the inquiry on "*What is Socio-Economic Status?*". To examine how the KB environment impacted students' negotiation of ideas on the topic of SES, we focused on students' notes of this KF segment. We traced and analysed each individual's theory development, from their initial theory to their better theory built on the scaffolds provided by their partner/peer, using three levels to categorise the extent of idea improvement and KB discourse (See Table 2).

Table 2: Three levels of KB Discourse for Stage 2 Inquiry.

Level	Descriptions	Examples
Level 1	Initial theory and peer scaffolding provided *limited avenues* for idea improvement.	Suggestions and questions in scaffolding were inadequate; student was unable to proceed to formulate his/her better theory.
Level 2	Initial theory and peer scaffolding provided *potential* for idea improvement.	Suggestions and questions in scaffolding were constructive but student was unable to proceed to formulate his/her better theory due to the lack of time.
Level 3	Initial theory and peer scaffolding *led to* idea improvement.	Suggestions and questions in scaffolding were constructive and student was able to formulate his/her better theory.

Stage 2 Findings

It is evident from the results that there was active involvement in theory development and KB discourse of the concept of SES. Out of the 27 entries, 37% managed to reach level 3, 52% were at level 2 and remaining 11% were at level 1. In examining the development process, most partners provided scaffolds that encouraged the students to include examples to support their initial theory. An example of a pair of students' KB dialogue that led to idea improvement (Level 3) can be seen below:

Student A provided an initial theory based on the inquiry using *"My Theory"* scaffold:

My Theory: "I feel that socioeconomic status (SES) is these two terms, economic and sociological combined that is a social standing or class of an individual or group. It is often measured as a combination of education, income and occupation. SES is more commonly used to depict an economic difference in society as a whole. I feel that Socioeconomic status is typically broken into three levels (high, middle, and low) to describe the three places a family or an individual may fall into. When placing a family or individual into one of these categories, any or all of the three variables (income, education, and occupation) can be assessed."

In Epistemic Agency, student B build-on to student A's initial theory and provided feedback with the use of a KB scaffold *"I need to understand"*:

I need to understand: "Your paraphrasing is good, though you lack examples. What are some examples of a socio-economic? And what do countries under socio-economic do?"

With the peer scaffolding, student A internalised student B's feedback and made improvements on her theory using *"My Better Theory"*:

> *My Better Theory: "I feel that social economic status can shape a person's identity. Socio-economic status refers to an economic situation shared by a group of people and some determinants are occupation, income, education and ownership of wealth. I feel that Socio-economic status is typically broken into three levels (high, middle, and low) to describe the three places a family or an individual may fall into.* ***For example, usually, people with a higher socio-economic status gets to experience fine dining or places where it is private or reserved for them whereas activities such as basketball are accessible to everyone. Another example is that the lower income gets assistance with bursary or subsidies while the higher income will be taxed more."***

Through the KB discourse, student A improved on her idea on SES with supporting examples of how groups of people with different SES have varied experiences and activities.

A few even managed to bring forth the concept of stereotype among the various SES groups; a chapter 6 concept that would be covered in subsequent SS lessons. One example of this can be seen from student C's better theory after his partner build-on to his initial theory to include examples as well:

> *My better theory: "Social-Economic status (SES) refers to the social class of a person. This is normally divided into low,middle and high. Usually lower class has lower form of education. While, higher class has a higher form of education. But this differs from time to time. <u>For example, people with low education can take over their family business and become a higher class. While, people with higher education can also drop to the lower class. Especially, when they can't find a job</u>."*

As seen from the example provided, student C constructed his improved idea differently by bringing forth the idea that classifying various levels of SES to their educational attainment is stereotypical and provided alternative examples to challenge the assumptions made.

The findings strongly indicate that the KB approach helped enhance effective IBL where dialogue and scaffolding led to improvement on theories and ideas towards the inquiry question.

Stage 3 Inquiry (How can we help those who struggles to have their basic needs met?)

In the third stage, students were required to answer the following SRQ part (a) question – "*How can we help those who struggles to have their basic needs met? Explain your answer using one way"*. Stage 2 helped provide students with conceptual understanding of SES in preparation for stage 3. Before the implementation of stage 3, the teacher showed the class a Channel News Asia documentary video titled "Don't call us poor". As explained in the stage 3 lesson design rationale, the video helped present the authentic problem of the struggles faced by lower SES group and helped student to empathise with the group. After the video, students begin to formulate their initial theory to the inquiry with the teacher providing comments with the use of the KB scaffolds.

Analysis of Stage 3 Inquiry

Similar to the method adopted at stage 2, we traced and analysed each individual's theory development. Theories would be categorised based on the standard Levels of Response Marking Scheme (LORMS) of SRQ part (a) highlighted in the SS syllabus (See table 3). The levels awarded for their initial theories would be compared to the levels awarded for their better theories to examine the impact of KB in improving students' application of knowledge and construction of explanations.

Table 3: Levels of Response Marking Scheme (LORMS) for SRQ part (a).

Level	Descriptions	Examples
Level 1	Provides description to the topic.	Student did not identify any suitable way/recommendation as required by the question.
Level 2a	Identifies one way/ recommendation.	Student identified one way/recommendation as required by the question.
Level 2b	Provide description of one way/recommendation that was identified	Student provided descriptions/examples of the identified way/recommendation.
Level 3	Construct explanation of one way/recommendation	After meeting Level 2b, student went on to explain how the way/recommendation would help those who struggles to have their basic needs met.

Stage 3 Findings

Table 3 summarises the results of stage 3:

Table 3: Results of Stage 3 Theory Development

Initial Theory Level (LORMS)	No. of students at Initial Theory level	No. of students managed to improve one level from their initial theory	No. of students managed to improve two or more levels
1	6	2	1
2a	16	6	1
2b	3	2	N/A
3	0	N/A	N/A

Majority of students whose initial theories were at level 1 did not manage to provide one feasible way/recommendation. Below is a sample of a student's initial theory which was at level 1:

My theory: "We can help by understanding and not judging them based on their situation. Those who are already struggling do not want to be put down even more by others. We have to encourage and compliment them whenever we can. For example, we can motivate them to not give up hope and keep trying. Simple things like this will make them feel better about themselves. Therefore, we can help by understanding and not judging them based on their situation."

Teacher's feedback using the KB scaffoldings did lead to her correcting her initial theory to one based on a feasible way/recommendation:

My better theory: "we can create a donation drive so that their basic needs are met. By having a donation drive, the low SES people do not need to worry about spending money on these needs. For example, the salvation army can help distribute the things that was donated to the low SES people. This way, they do not need to spend financially but also get their basic necessity. Therefore, we can have a donation drive for them so that their basic needs are met."

Based on the LORMS, her better theory met the level 2b criteria where she provided one feasible way supported with an example on how the recommendation can work. Her notes suggest that the KB approach, through one round of dialogue and scaffolding, would help the student to not just correct her misconceptions but also led her to improve on her initial theory towards the inquiry question.

In summary, close to 50% of the students managed to correct their misconceptions and/or make improvements after re-evaluating the first round of feedback given by the teacher. Since constructing explanations requires a higher level of cognitive response, further dialogue and scaffolding would be needed to ensure students continue making improvements on their explanations.

Conclusion and discussion

Reflecting on the processes and results, the teacher felt that there are no limits to idea improvement and should have provided more allowance, especially at stage 3, for scaffolding between student to student and between teacher to student. This might provide more room for idea improvement and, perhaps, get more to move up to a higher level of response in stage 3. However, the trade-off for more opportunities of quality scaffolding is time. Balancing between completing the syllabus and allowing for more KB discourse would be a constrain that the teacher needs to learn to navigate better. Notwithstanding, within an examination culture, such constrain intensifies as the SS teacher would be incentivised to 'teach to the test' rather than allowing room for continuous critical discourse in the classroom (Baildon & Sim, 2009). It would be imperative for the teacher, in future lesson designs, to consider integrative use of KB and its technological affordances that can further develop students' ability to construct explanations which would qualify as high levels of response based on the standard LORMS.

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[1] A list of Knowledge Building Principles can be found through this link: https://www.kbsingapore.org/12-principles-of-kb.

[2] Link to article: https://www.todayonline.com/singapore/how-tell-if-someone-high-or-low-class-poll-gets-interesting-replies-singaporeans.

[3] Link to Channel News Asia documentary: https://www.channelnewsasia.com/news/video-on-demand/dont-call-us-poor.

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Students Taking Charge at the Highest Levels: Cross-Community Engagement in Design Mode with Knowledge Forum Analytic Tools

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Abstract: One of the core aims of Knowledge Building is to move students toward higher levels of agency. The design challenge for Knowledge Forum is to provide supports "attuned to the self-organizing character of learning" through powerful feedback mechanisms that enable students to make reflexive and progress-oriented decisions that sustain collective knowledge advancement. This study follows three design iterations of metadiscourse with 8- and 11-year old students, culminating in a cross-community discussion of next-generation analytics for Knowledge Forum at the 2019 Knowledge Building Summer Institute. Through metadiscourse, students demonstrated sophisticated interpretations of their online activities with the Knowledge Forum analytic tools. Not only were they honest and open about receiving feedback through novel forms of data visualization, they were also aware of the potential limitations of these tools and offered thoughtful and insightful feedback for our engineers. Pedagogical and technological implications are discussed within the context of nurturing the emergence of new competencies, such as design thinking and computational literacy.

Introduction

Education for the Knowledge Age must shift from teaching students as passive receivers of knowledge to empowering them as active creators of knowledge (Bereiter, 2002; Tan, So, & Yeo, 2014; Chan et al., 2020). For more than three decades, Knowledge Building pedagogy and technology has been transforming the culture of teaching in schools so that students can assume higher levels of agency for creative knowledge work (Scardamalia & Bereiter, 1991; 1994; see Chen & Hong, 2016 for review). Toward that end, Knowledge Forum has been designed and refined over countless iterations with input from teachers, researchers, engineers, designers, and even students to facilitate sustained, creative work with ideas in K-12 classrooms. It should be noted that unlike typical educational technologies, Knowledge Forum aims to provide flexible, transparent, and customizable supports to enable students of all ages to design conceptual artifacts and pursue emergent, open-ended paths to advance collective understanding – such affordances range from contributing ideas in the form of multimedia objects (e.g., notes, drawings, videos, audio clips) to connecting ideas through build-ons and citations to reorganizing conceptual spaces by linking views and creating rising above views to visualizing collective progress on analytic tools.

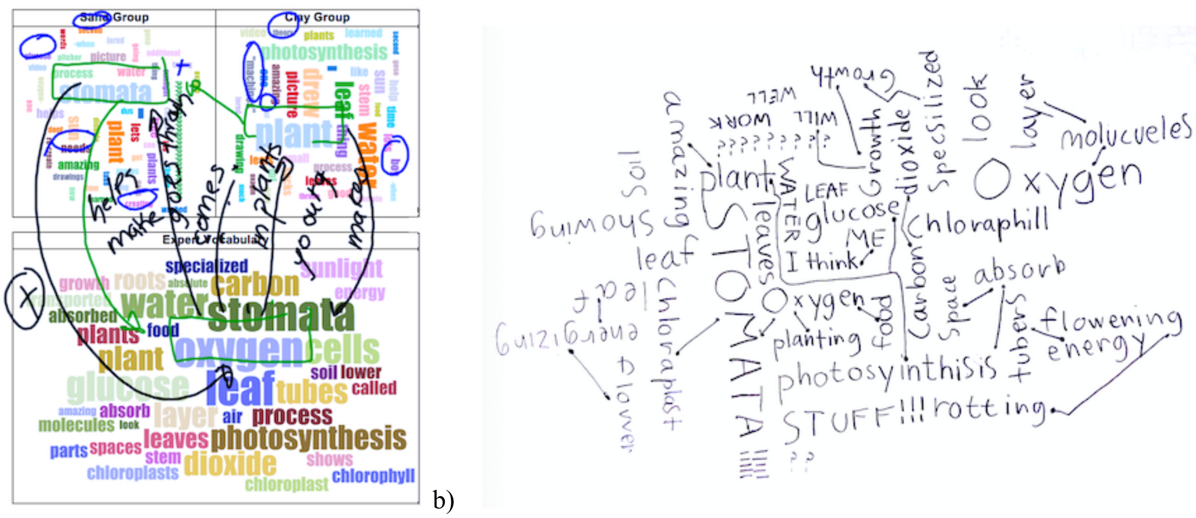
The design challenge is to provide supports "attuned to the self-organizing character of learning" (Scardamalia & Bereiter, 2014) through powerful feedback mechanisms that enable students to make reflexive and progress-oriented decisions (Chen & Zhang, 2016) that sustain collective knowledge advancement. One form of effective feedback mechanism is metadiscourse, which involves metacognition, meta-theory, and meta-conversation (Lei & Chan, 2018). Past research conducted in school classrooms reveal that young students are capable of engaging in metadiscourse using the Knowledge Forum analytic tools. Moreover, they demonstrate the ability to self-organize in productive ways that advance community knowledge. For example, 7-year olds can reflect on the state of their community knowledge through comparative word clouds and use visualizations of expert vocabulary to improve their ideas and become a more discursively connected community (Resendes et al., 2015). 8-year olds can identify promising ideas in their discourse to revise existing ideas and pursue novel areas of interest that enrich the scientific sophistication of their community knowledge (Chen et al., 2015). 10-year olds can identify connections across inquiry threads on the Idea Thread Mapper and co-organize social structures based on emergent interests to channel more collaborative and productive knowledge practices (Tao & Zhang, 2018). These research advances have informed the latest iteration of the suite of analytic tools in Knowledge Forum (Scardamalia & Bereiter, in press), which support embedded assessment in daily classroom practices so that teachers as well as students can initiate metadiscourse during Knowledge Building. Table 1 provides an overview of some of these analytic tools from the perspective of researchers, teachers, and students that has resulted from our work together.

In this paper, we elaborate on three design iterations of metadiscourse in- and out-of classrooms with primary-age students. In the first iteration, Thelma used the word cloud tool with her grade 3 students (8-year olds) to reflect on their study of plants in science class. In the second iteration, Darlene used various analytic tools with her grade 6 students (11-year olds) to reflect on their study of humanitarian crises in social studies class. In the third iteration, Thelma's and Darlene's students worked together to explore each other's KF communities using the analytic tools and discussed possible limitations and areas of improvement for the analytic tools at the 2019 Knowledge Building Summer Institute. These young students' intuitive design ideas and sophisticated interpretations of data visualizations are discussed in light of two major implications: technological implications for the design of next-generation Knowledge Forum analytics and pedagogical implications for nurturing the emergence of new competencies, such as design thinking (Martin, 2009) and computational literacy (DiSessa, 2018).

Design 1: Metadiscourse in Grade 3 Science

In the first design iteration, Thelma facilitated a metadiscourse session with her grade 3 class (n = 22) using the word cloud tool. After studying plants for a few months, students had written notes about how plants grow, plant roots, stems, and leaves, and the process of photosynthesis. Students also watched time-lapsed videos of beans growing and diagrammed their theories of how seeds turn into plants. As their discussions progressed, students became increasingly curious about the process of photosynthesis.

To address this emergent interest, Thelma showed her students a video that described the process of photosynthesis at the cellular level (generally shown in secondary biology class). Students then worked in half-groups to revisit their ideas and build on each other's notes and drawings with new scaffolds, such as "A new concept I learned", "A new fact I learned", "My improved theory is", and "I still need to understand". Figure 1a (top) shows that while the Sand group primarily focused on the concept of "stomata", the Clay group primarily focused on the concept of "water". Both groups had picked up the idea of "oxygen" from the video, but it was not as prominent in their discourse as it was in the expert discourse (bottom). During the metadiscourse session, the whole class came together to examine Figure 1a so that they could explore the concepts discussed in each group (top) as well as the concepts discussed in the transcript of the video they watched (bottom). The purpose of this discussion was to reflect on the similarities and differences between each group in search for possible connections and overarching themes about photosynthesis.



a) b)

Figure 1. a) KF word clouds of student discourse (top) and expert discourse (bottom) about photosynthesis and b) student-generated word cloud after metadiscourse session.

While students shared their observations and new insights, Thelma annotated Figure 1a. Important keywords identified by students are circled in blue and new connections made are written in black. The rise above explanation (in green) that came out of their metadiscourse is that "plants are like machines that make oxygen" and "oxygen goes in and out of plants through the stomata in the leaves". To synthesize their new understanding, students worked in small groups of three or four to draw their own word clouds. During this time, some students decided to rewatch the video and revisit their old notes to go deeper with their ideas. In Figure 1a, it can be seen that the KF word clouds of the half-groups included key concepts, such as "photosynthesis", "plant", "sun", "water", "leaf", and "stomata". In Figure 1b, however, it can be seen that a student-generated word cloud after the metadiscourse session had a richer vocabulary than the two automated word clouds combined. The students in this small group included expert concepts such as "glucose", "oxygen", "carbon dioxide", "chloroplast", and "energy", but also added new ideas, such as "molecules", "layers", "tubers", "flowering", and "rotting". A more in-depth analysis of how their vocabulary evolved over the course of their Knowledge Building is reported in Ma and Akyea (2019).

Although it has been previously established that Knowledge Forum supports the literacy development of young students, including vocabulary growth (Sun & Zhang, 2010; Chen et al., 2015), written composition (Lin et al., 2018), and reading comprehension (Hong et al., 2020). Thelma's design iteration furthers this line of research by building directly on Resendes and colleagues' (2015) work with comparative word clouds. That is, not only can teacher-facilitated metadiscourse support the development of vocabulary growth and conceptual understanding, but students can also play a more active role during metadiscourse by identifying key concepts in their discourse and creating their own visualizations to assess the state of their community knowledge.

Design 2: Metadiscourse in Grade 6 Social Studies

In the second design iteration, Darlene facilitated a metadiscourse session with her grade 6 class (n = 18) using various analytic tools in Knowledge Forum. After studying humanitarian crises using the inquiry process for a few months, students had written notes about world health, human rights, child labour, plastic pollution, climate change, and natural disaster relief. Students also had the opportunity to connect with another class on Knowledge Forum to explore how charitable organizations like Red Cross operate in different countries. As their discussions progressed, their Knowledge Forum views became full of notes and build-on threads – some students felt overwhelmed navigating the messy views while other students felt stuck with their ideas. Darlene was concerned that if discussions continued to slow down, student interest and engagement would decline.

To address this emergent problem, Darlene worked with a researcher to design a metadiscourse session to sustain collective knowledge advancement. The purpose of this session was to experiment with different analytic tools and help students revisualize their discourse and reconsider their ideas from different perspectives. Figure 2 (top) shows a portion of the Knowledge Forum view about natural disaster relief which had over 100 notes. Because students were discussing how Red Cross responds to disaster relief in Canada and Mexico, the words "red" and "cross" were used 186 times in that view and the automated word cloud was dominated by those two words. Therefore, the lexical analysis tool was chosen in place of the word cloud tool for the metadiscourse session.

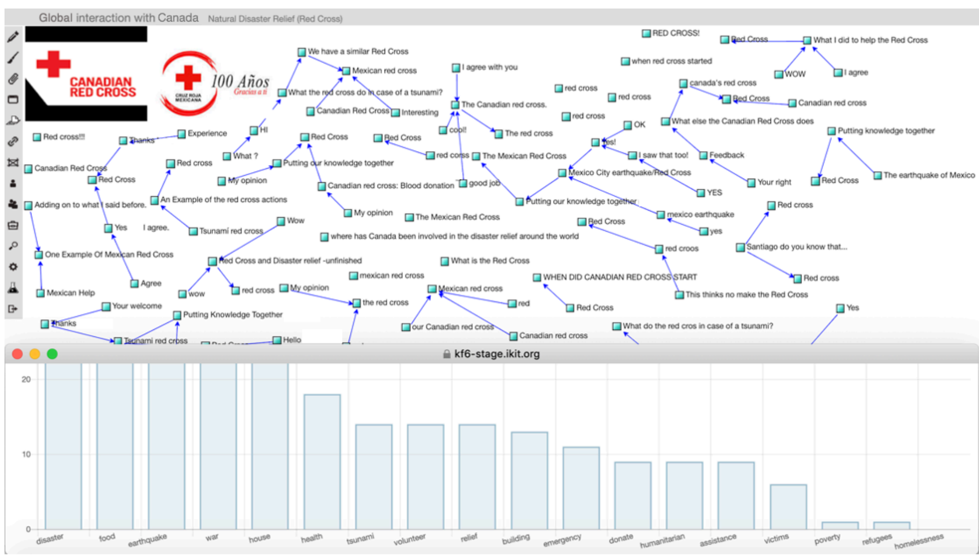


Figure 2. A Knowledge Forum view about natural disaster relief (top) with the lexical analysis tool displaying corresponding keywords (bottom) identified by students during metadiscourse session.

After reflecting on what they had learned in the natural disaster relief view, students identified a set of key concepts that they considered were critical for understanding the mission and work of the Red Cross, which included (but were not limited to): "disaster relief", "emergency assistance", "humanitarian", "earthquake", "tsunami", "victims", "refugees", "war", "food", "health", "house", "poverty", and "homelessness". Students had strong intuitions as to what the important words would be, and they gave complex interpretations as to why some words were used more frequently than others. For example, "earthquake" was one of the most commonly discussed natural disasters for relief aid because earthquakes occurred frequently in Mexico and that provided an authentic context for students in Mexico to share their ideas and experiences. "Food" and "housing" were other commonly discussed concepts because they were issues at the intersect of various humanitarian crises, including victims of natural disasters and victims of war. One key concept identified by students was "homelessness", however, it was not mentioned in the view. When students noticed this gap in their discourse, they were excited to introduce this new idea to expand discussions about housing by exploring how local and international initiatives could work together to solve the problem of homelessness. Students came to realize that one way to make new advances, is to search for more unique words rather than the popular words. As one student put it, “If you need ideas, this tool helps you see what is and isn’t talked about”.

Next, the students reflected on their community dynamics using the social network analysis tool, the activity dashboard, the scaffold tool, and the time machine tool. Because these tools were in beta form, students were asked to make judgements as to whether the analytic tools accurately reflected their shared experiences on Knowledge Forum. One of the students’ favourite tools was the social network analysis tool. Students were excited to play with the interactive network visualizations and fondly named it the “blob”. As each student explored their position in the class network, they were honest about whom they were building onto and not afraid to openly and respectfully discuss why they were not contributing in certain areas. Through this discussion, they developed a nuanced understanding of how to interpret sociograms: To be better connected to the community, you needed to both read more and write more. That is, a balanced build-on ratio (as indicated by the various colours in the network) was a more ideal contribution pattern than becoming the largest node with the most connections. In the words of one student, “The blob helps you be a better contributor”.

With this new insight, students explored the activity dashboard, which showed the proportion of their reading, writing, and revising behaviours for each student and the class as a whole. Students could easily read the pie graphs and infer what they needed to do to be a better contributor to the community. At this point, a student raised a concern about the activity dashboard. He wondered whether this analytic tool considered the length of a note by counting the number of words in the notes because a good contributor can also be someone who writes fewer but longer notes. Students agreed that there were multiple ways to be a “good contributor” to the community and that both quantitative and qualitative analyses would be needed to inform this type of assessment.

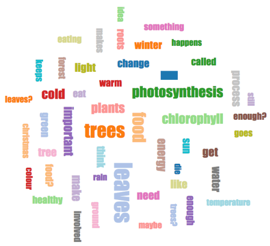
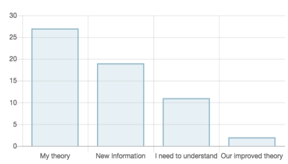
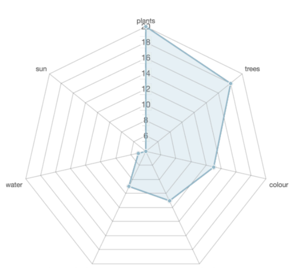
The scaffold growth tool served as another way to examine their contribution patterns. Students appreciated having a variety of “sentence starters” as entry points into their discussions but noted that they had a tendency to use some more frequently than others. For example, while “My theory” and “New information” were easier to use, “A better theory” and “Putting our knowledge together” were more difficult to use. Based on this reflection, a student suggested revising the scaffolds to encourage more diverse contributions in their discussions. Together, they designed the new scaffolds: “I agree/disagree because”, “A new theory could be”, “Putting our knowledge together, I now understand”, and “A better understanding”.

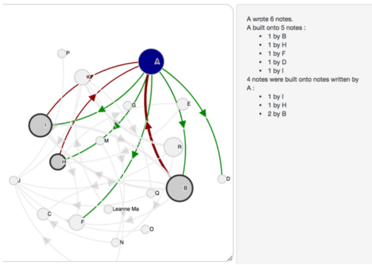
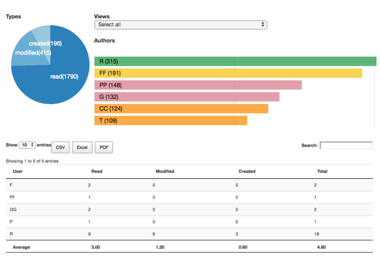
Finally, the students explored the time machine tool. This tool was another class favourite which one student coined as the “video surveillance” for their community. In addition to using the dynamic playback visualization to assess community knowledge growth where build-ons grew, students devised a strategy to use this tool to see when new questions were entered and where certain questions were not answered (i.e., no build-ons). In doing so, they could monitor their ongoing learning and find where they needed to contribute more ideas. The students’ metadiscourse inspired Darlene to envision a new analytic tool wherein keywords could be visualized as an interactive line graph to see when certain keywords emerged and how their frequency changed over time.

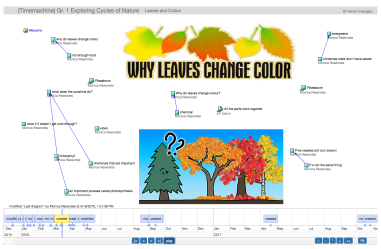
In summary, Darlene and her students found that the analytic tools transformed the way they engaged in formative assessment. Each student was able to find a different analytic tool to see where they could improve upon and support their learning forward. At times, the activity dashboard triggered some healthy competition, however, students remained thoughtful and supportive in their contributions as they were engaged in topics that were personally meaningful to them. Similar to Thelma, Darlene facilitated the metadiscourse session in a way that supported student agency and engagement. In addition to encouraging students to identify key concepts in their discourse, it was the students themselves who identified gaps in their community knowledge, found promising areas that could be expanded into new pursuits, and planned next steps to advance their community knowledge. It is interesting to note that although Darlene did not use the promising ideas tool (Chen et al., 2015) or Idea Thread Mapper (Tao & Zhang, 2018), her students engaged in similar reflection processes. Moreover, her students’ reflections around the different visualizations enabled them to take ownership over their Knowledge Building in a broader sense: After critically examining the state of their community knowledge, they deconstructed and reconstructed their interaction dynamics and discourse moves in order to operate more powerfully as a community. Table 1 (column 3) provides a further elaboration of student reflections around the Knowledge Forum analytic tools.

Table 1: Overview of KF Analytic tools from researchers, teachers, and students.

RESEARCHERS	TEACHERS	STUDENTS
WORD CLOUD		

This tool shows the big ideas in the student discourse.  **Reflection questions:** - What are the big ideas everyone is talking about? - What ideas are missing?	Knowledge Building starts with real ideas and is sustained through idea diversity. The Word Cloud tool can help you assess whether students are engaging with big ideas in the curriculum and using key terms in their online discourse. Asking students to reflect on the vocabulary makeup of their discussions can bring to light both what concepts are popular and what ideas are missing and/or neglected in their work.	The word cloud is a cloud of the most used words of the topic/ conversation. It basically gathers all the words you use in the topic and puts them inside. Big words are used most, and the smaller words are used less.
SCAFFOLD GROWTH		
This tool shows the types of contributions in the student discourse.  **Reflection questions:** - What types of contributions are needed to move our community knowledge forward?	The more diverse the kinds of ideas and the kinds of contributions in the student discourse, the more likely knowledge advancement is happening. The Scaffold Growth tool helps you visualize the types of contribution and engagement patterns in Knowledge Forum. Exploring the graph with students can inspire reflective conversations about the state of the community's knowledge at a given time.	Scaffold Growth shows the most frequent sentence starters that we use in a certain community. Some ways we're able to visualize is to see which exact contributions use each sentence starters. The most common way is the bar chart, which is a chart with each scaffold. The other way is the radar chart, which is a radar looking chart that has a number line going horizontally.
LEXICAL ANALYSIS		
This tool shows the growth of concepts in the community knowledge.  **Reflection questions:** - How are the big ideas in the community knowledge related to one another?	As students build on each other's ideas, the community knowledge grows in an interconnected manner. The Lexical Analysis tool helps you visualize which ideas and concepts grow together. Exploring the graph with students can inspire reflective conversations about the state of the community knowledge at a given time.	Lexical Analysis is a very useful tool where you input a name or a word, and it will be highlighted on each contribution it will also be shown on a chart how many times it has been used. We use it when we are searching for other people's contributions, so it's easier to find the contributions. There is also a bar chart showing which words are used the most which is very helpful for expanding our vocabulary and not using the same word repeatedly.

<table>
<tr><th colspan="3">IDEAS BUILDING</th></tr>
<tr><td>This tool shows the patterns of collaboration in the community.

Reflection questions:
- Who is reading/building on whom? Why or why not?
- How can we get all members of our community engaged?</td><td>Community building and Knowledge Building emerge in parallel. The Ideas Building tool helps you assess how your class is forming as a community. At a glance, you can see the degree of connectedness at the group-level. When you click on a student, you can see the build-on relation between that student and others in the community. Asking students to reflect on their collaboration patterns helps foster a sense of collective responsibility.</td><td>Ideas Building is a very interesting tool. This tool can show you all your connections to other students' contributions. When you open this analytical tool, you will see multiple circles with names on them, with lines connecting other circles. The more students that make contributions, the more circles you'll see, and it will be crowded with connections. The bigger an author's circle, the more connections they have with other people. We sometimes use this tool to reflect if we need to contribute more or build on to people more, showing more collaboration among students.</td></tr>
<tr><th colspan="3">ACTIVITY DASHBOARD</th></tr>
<tr><td>This tool shows an overview of basic KF activities

Reflection questions:
- How am I participating and contributing relative to other community members?</td><td>Knowledge Building is pervasive, and students often continue working on their ideas outside of school hours. The Activity Dashboard tool gives an overview of basic KF activities, such as the group totals and group averages of reading, writing, and editing behaviours. It also shows you the distribution of contributions by author. In other words, it can help you gage whether or not students are taking initiative based on how active they are relative to the group as a whole.</td><td>Activity Dashboard is a useful tool for many reasons. It gives an overview of the basic KF activities, such as the number of contributions you have made, read, and modified. It also shows whether the students are contributing enough to the group overall, like how much you have read, contributed, and modified over time. The visualizer is good because you can see what you have done good on and what you can work on for the future. The cool thing about the visualizer is that you can see what you have improved on and how much the class has grown.</td></tr>
<tr><th colspan="3">TIME MACHINE</th></tr>
</table>

This tool shows the growth of community knowledge over time.  **Reflection questions:** - How have our ideas evolved? - Are there still ideas that need our help to grow?	Continual idea improvement is the central driving force of Knowledge Building. The Time Machine tool shows the development of student thinking and the evolution of community knowledge in a given KF view. You can stop, rewind, or fast-forward through the animation to hone in on different points of the view development. Exploring the history of the view with students can help them develop a rise above perspective on their community knowledge.	The time machine is an analytical tool that shows how a view evolves and how our thinking develops from when this view was created to the present time. It can provide many uses like knowing when you made certain contributions or seeing how long someone has been waiting for a response to a question. An idea to add to make this tool even better could be for everyone to be able to slow down how fast it evolves, so you can read it easier and see all the contributions that were added, including all the connections and progress among students.

Design 3: Cross-Community Engagement in Metadiscourse

In the third design iteration, Thelma's and Darlene's students engaged in a metadiscourse session using various analytic tools in Knowledge Forum at the 2019 Knowledge Building Summer Institute held in conjunction with the Annual Meeting of the American Educational Research Association in Toronto, Canada. First the grade 6 students taught the grade 3 students how to use the analytic tools, then they used the analytic tools to explore the evolution of ideas in each other's KF communities. Students were excited to hear about each others' work and see how different features of Knowledge Forum were being used in different contexts. For example, the grade 6 students were impressed by the grade 3 students' ease of use of the drawing tool to express their ideas as diagrams and graphs and learned that notes and drawings could be integrated into rise aboves to synthesize ideas.

Even though the grade 6 students were studying social studies and the grade 3 students were studying science, their metadiscourse eventually brought them to a point of conceptual convergence. As the grade 3 students explained their Knowledge Building journey from studying oxygen in plants to carbon absorption on earth, they honed in on a few questions they were grappling with, such as why certain countries had more carbon absorption than others, and what would happen on earth if there was too much or too little carbon absorption. This sparked a lively discussion about socioscientific issues, such as climate change, deforestation, and pollution, to which one grade 6 student asked, "Is there anything we can do to help carbon absorption?". This question became another line of investigation for the grade 3 students afterward.

Similar to the grade 6 students, the grade 3 students were very fond of the social network analysis and time machine tools. The grade 3 students liked how the time machine tool could be used to see when the view was reorganized to reflect new advances and to revisit past versions to retrieve lost or deleted notes. One student suggested that the tool could be improved by helping them flag redundant or inappropriate comments. Like the grade 6 students, the grade 3 students had a common tendency to use the scaffold "My theory". The grade 3 students noted that the scaffold growth tool could help them contribute to the community in different ways, such as selecting a less frequently used scaffold like "I'd like to add on". However, another grade 3 student pointed out that newer scaffolds would have a lower cumulative number, so the graph would need to be adjusted accordingly.

Altogether, both groups of students benefited from the metadiscourse session. Darlene's students continued using the analytic tools to engage in metadiscourse in other subject areas including English class which supported rise above analyses of emergent themes across the different texts they were reading. Thelma's students continued using the analytic tools in small groups for the remainder of the school year. Metadiscourse became so pervasive in their daily classroom practices, that some students even suggested importing the visualizations as images or notes in Knowledge Forum so that they could be built on further.

Discussion

In this paper, we explored three design iterations of metadiscourse with primary-age students. In Thelma's design iteration with her grade 3 students, she extended past designs of comparing automated word clouds of student and expert discourse to include more open-ended, student-generated word clouds. In Darlene's design iteration with her grade 6 students, she used the lexical analysis tool to revisualize their discourse in ways that helped them determine important and promising ideas that needed further work. Through metadiscourse supported by analytic tools in Knowledge Forum, both Thelma and Darlene empowered their students to explore new forms of engagement to sustain community knowledge advancement. One major finding coming from the third design iteration is that students as young as 8 and 11 years of age can offer sophisticated interpretations of their online activities with the Knowledge Forum analytic tools. Not only were they open to novel forms of data visualization, such as sociograms and radar charts, they were aware of the potential limitations of these data visualizations and offered insightful reflections for our engineers. Some of the concerns they have raised are currently being debated by experts in the field of learning analytics and educational technology (Selwyn, 2019). Our research team is now incorporating teachers' and students' recommendations in the next design iteration of the Knowledge Forum analytic tools. For example, engineers are creating new tools to transform word count into measures of lexical richness and conceptual diversity. The word cloud tool is also being integrated with the lexical analysis tool to allow for filtering of keywords and multiple visualizations in the form of bar, radar, and line graphs (see for example Ma, 2018).

Another major takeaway from this work is that through continued use of Knowledge Forum, students became designers in every possible way. Students treated the analytic tools as conceptual artifacts (i.e., objects to think with) and found enjoyment in experimenting with new strategies and tinkering around with new tools as learning scientists and engineers would do. By adopting an "improvable ideas" mindset, they were quick to offer creative ways to use those tools to support their learning. We find it fascinating how their metadiscourse sessions about improving their community knowledge and community dynamics evolved into design sessions for improving assessment tools to provide feedback for their community – past research has identified the role of metadiscourse in helping students revise their knowledge goals but not necessarily refine their assessment methods (e.g., Chen et al., 2015; Tao & Zhang, 2018). Of course, we are not suggesting that every metadiscourse session should unfold in such a manner, and we are well aware of the potential risk of reinforcing performativity in schools when too much value is given to prescriptive assessments derived from superficially-constructed quantitative measures. We do maintain, however, that discourse and metadiscourse are critical for advancing students', as well as our Knowledge Building. For this reason, we propose that if students are truly to assume higher levels of agency for creative knowledge work, they ought to play some role in helping us design tools and environments optimized for knowledge creation.

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Enhancing Pre-School Teachers' Professional Development using Knowledge Building during Home-Based Learning

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Abstract: Home-Based Learning has emerged as a viable alternative for teaching and learning during the COVID-19 situation but there was considerable impact on teachers' professional development, especially in pre-schools where online learning had not been implemented before on a large scale. We investigated how a pre-school teacher used knowledge building to enhance her professional development by analyzing data on the Knowledge Forum and weekly Professional Learning Community sessions during Home-Based Learning. Findings show that the teacher was able to achieve higher levels of adaptability, original design thinking as well as enhanced leadership and collaboration with other staff. We also discuss how pre-school teachers can use knowledge building to facilitate online learning and further support teachers' professional development in future work.

Introduction

The increasing affordance of technologies and pervasiveness of online learning platforms in schools has led to a gradual normalization of blended learning for most K-12 students. Although online learning tends to occur at predesignated periods of a teaching term before teachers revert to the planned curriculum in schools when students return to schools, the ongoing COVID-19 pandemic has caused global disruption to almost all aspects of life, including ways in which students have to learn in online environments different from traditional school settings.

In Singapore, teachers and students were asked to shift towards Home-Based Learning (HBL) to ensure that students would continue to receive formal education even under such unprecedented circumstances. Although K-12 teachers possess some experience in engaging students using online platforms and resources, these conditions are, however, relatively new to pre-schools, especially when considering the students' relatively young age and ability to engage with online resources for effective learning. Further, as teachers focus on adapting their teaching practices and materials online within a short timeframe, lesser time was available for teachers' professional development during the extended period of Home-Based Learning. Therefore, the transition from traditional face-to-face teaching to conducting online lessons for pre-school students had impacted and hindered pre-school teachers' professional development.

However, Knowledge Building (KB) principles and technologies can be used to ground teachers' professional development by offering a community approach to overcoming issues. This paper investigates how KB can enhance the professional development of teachers, specifically pre-school teachers, across various platforms, such as the Professional Learning Community (PLC) sessions, the Knowledge Forum, and both online lessons and the physical classroom.

Literature Review

Blended and Home-Based Learning for Pre-Schools

Blended learning converges two different types of learning environment, specifically traditional face-to-face classroom environment and computer-mediated learning environment (Bersin,2004; Bonk & Graham, 2012). It also offers greater synchronous and asynchronous interactions between students and teachers. In previous studies involving blended learning in elementary school settings (Lossman & So, 2010; So, Seah & Toh-Heng, 2010), findings show that online discourse contained more diverse ideas that students use to share misconceptions and raise questions compared to classroom discourse, which had more Initiation-Response-Evaluation (I-R-E) patterns. The latter study also showed that mixed-ability and high-achieving primary school students could work towards advancing individual and collective knowledge with the design and enactment of knowledge-building communities.

The COVID-19 pandemic has forced schools and educational institutes to replace face-to-face lessons with online platforms to conduct classes. This form of Home-Based Learning (HBL) has now become part of a new normal and the following relevant literature is also nascent. The impact of HBL has been intently studied, with focus on: the use of instructional strategies to facilitate students' online learning (e.g., Bao, 2020) and explorations on the difficulties experienced by teachers due to weaknesses in infrastructure (Zhu & Liu, 2020), and insufficient technical training for teachers to transition to online learning (Zhang et al., 2020).

Some of these studies have shown that knowledge building can be used with younger students in blended learning settings, indicating that the pedagogy is not limited to older students in secondary (Cheong & Cheung, 2008) or tertiary education (Cheung & Hew, 2011) institutes. Existing research on blended learning using knowledge building within pre-schools, however, remain limited, mainly due to the dominant mode of interactions and curriculum for young students in pre-school or childcare settings. The foundations for such interactions are based on developmental theory and Reggio Emilia-insipired curriculum. The developmental theory focuses more on socializations and the development of basic numeracy and literacy skills while the Reggio Emilia-inspired curriculum focuses on the development of social and cognitive abilities (Hong, Shaffer & Han, 2017). Such a curriculum uses visual media, in the form of student drawings, to explore students current understandings, how their previous understandings are reconstructed and how they co-construct their understandings of the phenomena investigated (Katz, 1998). Another reason is due to the nature of care that has to be provided, such as provisioning for nap and mealtimes, resulting in lesser time for teachers to orchestrate both online and offline teaching for students. Furthermore, the gaps identified during the implementation of Home-Based Learning, such as the lack of pedagogical training and the impact on teachers' professional development, were not adequately addressed. This paper proposes the use of the KB as a more holistic teaching approach that incorporates a blended use of online tools and face-to-face lessons to improve students' ideas and deepen their understanding, while also ensuring teacher's professional development is not neglected.

Teachers' Professional Development and Professional Learning Communities in Pre-Schools

Professional development is crucial for ensuring that in-service teachers continuously improve their teaching practice while adapting to the changing needs of students, such as the development of 21st-century skills competencies that require teacher facilitation while still being engaged in pedagogy (Luke et al., 2005). By being involved in research-based pedagogy, active collaborations between teachers and researchers can ensure teachers' professional development of teaching practices can meet the needs of the globalized world, so that students can thrive in this fast-changing and globalised world (Ministry of Education, 2020) .

The pedagogy of teaching in the local context involves rote learning where 'learners in such classrooms are reduced to passive recipients' with 'little creativity or flexibility in such approaches' which led to rigid and disciplined structure of teaching (Saravanan, 2005). Such training can produce a strong foundation for factual information and basic skills, as evidenced by good performance on international benchmarks such as the Programme for International Student Assessment (PISA, 2018), but it may also lead to a "threshold effect' (Luke, 2005; Koh, Kim & Luke, 2009). This threshold effect impacts students by constraining higher-order thinking, critical and creative thinking when highly disciplined methods of teaching limit students' access to intrinsically meaningful learning, as also shown in other studies (Cheah & Robbins, 1998; Luke et al., 2005). Such limitations may inhibit students from developing the skills and competencies needed to navigate the emerging knowledge economies. Therefore, there is a greater need for schools to shift from wholly traditional classroom towards a blended type of learning for students to acquire critical 21st century competencies to seize new and exciting opportunities in the globalised world.

The concept of Professional Learning Communities (PLCs) was introduced to pre-schools through KB as an effort to aid the deepening of teachers' collective understanding through social interactions and knowledge construction. The PLCs are designed with the assumption that individual and collective pedagogical understandings are deepened through social interactions and discourse that fosters the collective construction of knowledge. Within the PLCs, teachers share lesson plans, challenges and teaching strategies to resolve arising problems and refine lesson plans. Through constant collaboration with others to improve ideas, teachers can continuously engage in reflective discourse to develop a common understanding (Laferriere, Lamon & Chan, 2006).

Knowledge Building and the Knowledge Forum

Knowledge Building (KB; Scardamalia & Bereiter, 2006), as a non-linear approach to teaching and learning, proposes a vision of the classroom as a knowledge creation organization. When implemented in our context, KB's 12 principles (Scardamalia, 2002) provide teachers a space for discussions, share diverse and authentic ideas, allow students to take responsibility of their ideas and democratize knowledge to be pervasive within and outside of school. The Knowledge

Forum (KF) is used as an online environment that supports asynchronous knowledge building communication through sharing of ideas and knowledge in the PLC with the use of scaffolds.

Based on limited research on how blended learning can be implemented in pre-schools and improve the professional development of pre-school teachers, this paper investigates how a pre-school teacher was able to enhance her professional development through the use of knowledge building across several teaching and learning platforms. We ask the following research question to guide our study: How do pre-school teachers use knowledge building to enhance their professional development during blended and Home-Based Learning?

Methods

Participants and Settings

The participants in this study include six teachers, two of whom are the English and Chinese language teachers involved in face-to-face teaching but are new to knowledge building. The other three teachers had a cycle's worth of experience in the development of a psychologically safe environment, where they engaged with the form teachers in respectful and turn-taking behaviours, to design and coordinate lesson plans. The last teacher, with four months of experience in engaging her students in Knowledge Building (KB) was also involved, together with the three teachers, in the PLC and conducted knowledge building using KF.

Data Collection and Processing

As this study is part of a larger and ongoing research on pre-school teachers' professional development, we decided to specifically focus on the HBL period and the subsequent physical classroom lessons. The study aimed to examine how pre-school teachers enhanced their professional development during HBL. The English teachers' data were collected from three sources across 2 months, namely, the physical classroom where teachers conduct their lessons, the PLC where teachers congregate to share and discuss, and from the Knowledge Forum. The English teachers' data was selected for the analysis in this paper as she was involved in the entire HBL cycle, as compared to the Chinese teacher who could only attend certain parts of the cycle and provide partial data. The PLC sessions were conducted via Zoom, a video conference application, and recorded as videos, which consist of teachers self-reporting summaries of happenings in the classroom or during lessons. This dataset from the PLC sessions also comprises of suggestions and feedback from teachers on how future lesson plans can be improved, imagined, and better implemented, alongside several mentions of problems that arose during lessons. The teachers' discussions and knowledge building on the KF was based on the theme of "Our Amazing Body System".

Procedures and Data Analysis

Data collected from this study was firstly coded according to a Teaching Practice framework proposed by Kim (2019). Referencing Kim (2019) and York-Barr and Duke's study (2004), we identified four components of teaching practice necessary to inform teachers' professional development in PLCs and the KF- adaptability, design thinking, teacher leadership, and teacher collaboration. Sub-components for design-thinking and teacher leadership were adapted from their papers, while the other sub-components for adaptability and teacher collaboration were generated by us to code the teacher's adaptation of practice to suit online learning and collaboration through knowledge building. The adaptation of lessons based on parents' involvement was included in the analysis as pre-school students may require more external assistance during the learning process and they often lack the ability or finesse to conduct research or perform certain student activities alone.

The principles of KB can map onto the framework with adaptability aligning with 'improvable ideas' where teachers are constantly working on improving their lesson designs through feedback shared by others, from parents or their peers. The component of design thinking maps onto several principles like 'real ideas, authentic problems' and 'epistemic agency' where teachers would think out-of-the-box to make lessons relatable to the students. This involves giving students more ownership in the learning process so that students' ideas take centre-stage in inquiry. The principle of 'community knowledge, collective responsibility' embodies teacher collaboration where teachers share responsibility for the advancement of knowledge in the teacher's classroom and for their professional development. Lastly, the principles of 'symmetrical knowledge advancement' and 'pervasive knowledge building' reflects teacher leadership where teachers synchronize lessons for a more in-depth inquiry for students and collaborate with parents to encourage building of knowledge outside of school. We propose Table 1 as a new framework that guides future analyses on how pre-school teachers and, to a certain extent, other teachers can enhance their professional development during blended learning or HBL.

Table 1: Coding Scheme for Teachers' Professional Teaching Practice, adapted from Kim (2019) and York-Barr and Duke (2004).

Components	Sub-components	Scale	Description
Adaptability	Adapting lessons based on feedback from parents' involvement	Low	Difficulty in adapting lessons based on the response of parents' involvement in Knowledge Building.
		Medium	Adapts future lessons based on the response of parents' involvement in Knowledge Building.
		High	Adapts and adjusts the ongoing lesson based on the response of parents' involvement in Knowledge Building.
	Adapting lessons based on feedback from PLC sessions	Low	Difficulty in adapting and incorporating feedback given during the PLC sessions in her lessons.
		Medium	Adapts feedback given during the PLC sessions in future lessons.
		High	Adapts and incorporates feedback given during the PLC sessions within an ongoing lesson.
Design Thinking	Think creatively	Low	Difficulty in generating creative and original activities for lessons.
		Medium	Develops original activities for upcoming lessons.
		High	Constructs and develops original activities in the ongoing lesson or amid ongoing situations.
	Experimenting with solutions	Low	Difficulty in experimenting with solutions.
		Medium	Experiments with existing and proven solutions.
		High	Generates original solution to address problem and experiment with it and adapt it accordingly based on feedback received from experimenting.
Teacher Collaboration	Teacher collaboration within a class	Low	Discusses ideas without the intention to implement; Raises problems without providing solutions; Struggles to coordinate lessons within a class.
		Medium	Discusses ideas and implementation of ideas for the upcoming lesson.

		High	Large degree of involvement with other teachers in classroom work to facilitate the lesson.
	Teacher collaboration between classes	Low	Discusses ideas without the intent to implement; Raises problems without providing solutions; Struggles to collaborate with other classes.
		Medium	Discusses ideas, strategies with implementations for the upcoming lesson.
		High	Large degree of involvement with teachers from other classes in designing classroom work to facilitate lessons.
Teacher Leadership	Coordination and management	Low	Discusses without any intent of coordinating lessons; Struggles to coordinate lessons.
		Medium	Develops an upcoming lesson plan that is coordinated between teachers.
		High	Develops future lesson plans that are relevant and coordinated between teachers.
	Contributions to the profession of teachers	Low	Struggles to develop or discuss strategies for teachers' professional development.
		Medium	Develops solutions that would help teachers in the short-term.
		High	Redesigns and develops solutions that aid teachers and their practice in the long-term.
	Parent and community involvement	Low	Presents parents with the students' work; Struggles to involve parents in Knowledge Building.
		Medium	Uses online tools to involve parents in building knowledge with their child in their own time.
		High	Develops activities to actively involve and engage parents to use Knowledge Building in the ongoing lesson.

Findings and Discussions

To answer the research question: "How do pre-school teachers use knowledge building to enhance their professional development during blended and Home-Based Learning?", we coded the collected data using the coding scheme proposed in Table 1. The dataset containing PLC sessions consists of a total of seven sessions, which were divided into two groups, namely the first half (1st to 3rd session) and second half (4th to 7th session), to showcase potential shifts in the components of the teacher's professional development throughout the study. The sub-components identified from the proposed framework were then analyzed and aggregated into an overview (see Figure 1) to present the different shifts during the teacher's professional development.

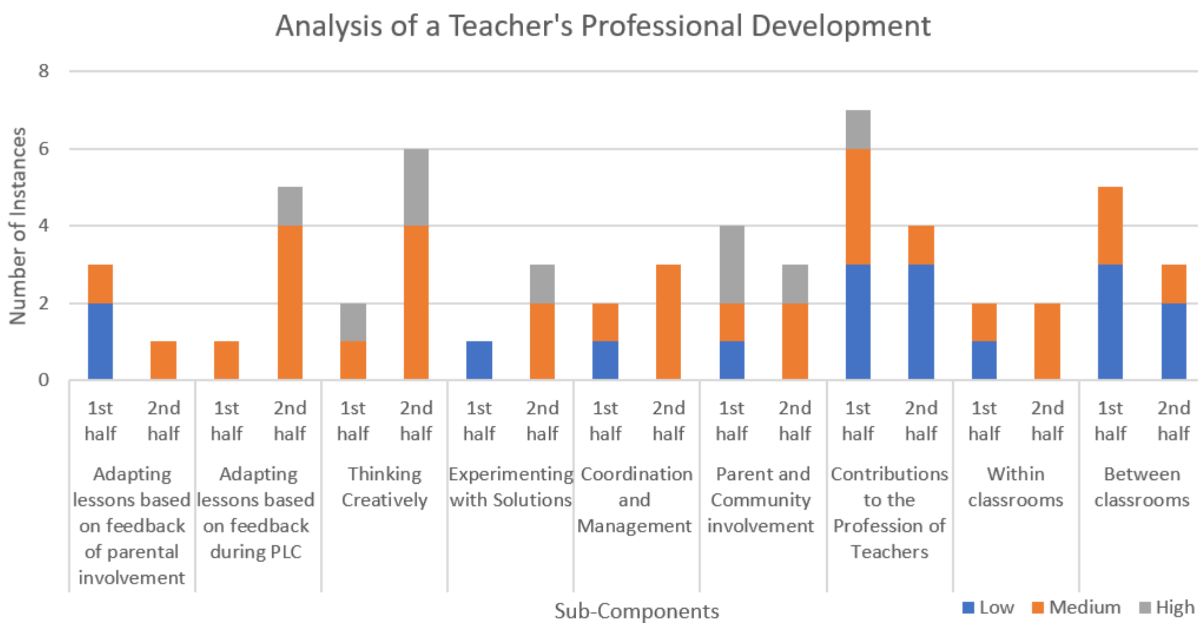

Figure 1. An overview of the different scales of sub-components displayed by the teacher across multiple PLC sessions and KF discourses.

From Figure 1, we identified several significant shifts of sub-components, from a lower to a higher level, as the teacher sought to enhance her professional development using knowledge building. After the following analyses, we have also identified examples of each sub-component in Table 2.

Adaptability – Feedback from Parental Involvement and PLC

First, there was a small shift in the teacher's adaptability based on feedback of parental involvement and a relatively higher shift in the teacher's adaptability based on feedback during the PLC.

During the PLC sessions, teachers discussed about the aim of the teaching cycle was to introduce and involve parents in knowledge building. However, there was uncertainty over how to continue with the lessons when only several parents indicated their interest to participate, after considering that the planned lessons require significant commitment and effort. The teachers eventually suggested that parental involvement can be perceived to be supplementary in nature instead. Following this feedback, the teachers continued to develop activities that were less demanding on the parents, and this level of activity resulted in a more moderate medium scale. Thereafter, weekly meetings were also held to continue providing the teacher with support, in the form of constant encouragement from non-teaching staff on how to involve parents in KB throughout the HBL period.

The feedback and ideas from the PLC sessions had also influenced the teachers' development of lessons. During the weekly meetings, both teaching and non-teaching staff provided third-person perspectives on a pool of ideas and resources that can be used for upcoming lessons, along with insights into how these ideas can be developed, even though this effort may not be transparent to the teacher who has to constantly engage the students during HBL. This has led the teacher to be able to achieve a higher level of adaptability for her lesson, with the continuous support and stream of ideas for use in subsequent lessons.

Design Thinking – Thinking Creatively and Experimenting with Solutions

A significant and higher shift was detected in the teacher's design thinking from the first to second half of sessions. The increase in creative thinking was due to the encouragement doled out during the PLC sessions, especially with regards to how parents can be continuously involved in KB discourse at home and also when assisting in the development of closer connections to topics that were discussed between the individual lessons. Further, the teacher's shift to a higher level of creative thinking was evidenced by an occasion when the teacher took advantage of the ongoing novel COVID-19 crisis to facilitate students' understanding of the pandemic and also discussed the benefits and use of masks with the students.

The teacher also displayed a shift towards higher levels of experimenting with solutions. The teachers discussed ways to help students connect what they had learnt during HBL and what can be brought into the physical classroom, with the suggestion of a Wonder Wall so that students can view the ideas that were shared online. In addition, the teacher experimented with a variety of solutions and provided students with the opportunity to exercise agency in their learning, by allowing students to decide the activity they want to conduct in order to facilitate deeper understanding of an assigned topic.

By following knowledge building as an idea-centric approach for teaching, the teacher constantly innovated and thought of creative ways to encourage students to inquire and generate ideas in the classroom. As the sessions progressed throughout the study, the teacher also became more creative in developing activities that would allow students to integrate their experiences and be open to experimenting with solutions to overcome unexpected challenges during learning.

Teacher Leadership – Coordination and Management, Parent and Community Involvement, and Contributions to the Profession of Teachers

Shifts towards higher levels of teacher leadership were identified, especially in the sub-components of coordination and management, and parent and community involvement. However, we detected a lower shift within the sub-component of contributions to the professions of teachers.

This trend could be explained with what was observed in the earlier PLC sessions, where the teacher discussed how the activities suggested on the KF can be sequenced and organized into a lesson plan. As the session progressed, the coordination and management of lessons became more organic with the teacher focusing on what students were trying to share and was able to better coordinate lessons based on how they could support the children in the development of ideas. Thereafter, lesser time and emphasis was needed for the sequencing of lessons and during the PLC sessions, the teachers were able to also share resources and exchange ideas to aid the teacher in managing lessons based on student ideas.

An explanation for the lower shift in the parent and community involvement may be due to the teachers' discussion and queries on how to involve parents in knowledge building. As teachers received feedback from parents in the subsequent lessons, a "Knowledge Building Time" document was developed to further encourage parent participation in knowledge building, and following the distribution of the document, the teacher had lesser time and resources to conduct her work, leading to a reduced sharing of parents' participation during the PLCs.

A lower shift and decreased number of contributions to the professions of teachers was also detected as the teacher was new to knowledge building and therefore, she was more susceptible to gaining advice from the more experienced teachers than being the one to provide valuable advice to others in her progress to support her professional development. However, as teachers in the study became more familiar and accustomed to the knowledge building approach, lesser supporting contributions were then offered by the teachers.

Teacher Collaboration – Collaboration with Teachers Within and Between Classes

Finally, there was a shift towards higher levels of collaboration with teachers within a class, but there was a decrease in transitioning to higher levels in teacher collaboration between classes.

The initial low levels in teacher collaboration within the classroom was due the teacher adoption of the KB approach, thus resulting in more discussions and lesser coordination of lessons. Through the weekly exchange in updates and lesson plans, the teacher was better able to identify similarities in the topic that was covered in the classroom, resulting in more coordination between the resources shared and the teachers' lesson plan on the same system with minimal overlap in the content covered. As a result, the teacher became more open to sharing her upcoming lessons and the resources for coordination.

The amount of teacher collaboration between classes decreased, likely due to the increase in teacher commitments that led to fewer discussions with teachers across classes. Moreover, as the teacher became more familiar with the KB approach, she could then develop idea-centric activities and lessons that require lesser support from other teachers to facilitate and help conduct her lesson.

Table 2: Examples of quotes from PLC transcripts for each of the sub-component

Components	Sub-Components	Quote from PLC transcripts	Our interpretations

Adaptability	Adapting lessons based on feedback from parental involvement	*Parents have not done the KB activities...so...I thought of trying out the experiments in the lessons itself...*	Adaptation of future lesson plans based on feedback given on parents' lack of involvement.
	Adapting lessons based on feedback from the PLC	*I took into consideration all the ideas that were thrown...*	Feedback and ideas shared during the PLC was accounted for to produce a revised lesson plan for the upcoming class.
Design Thinking	Thinking Creatively	*For the lesson this morning, we discussed more on viruses. So we built onto the- the mask making so this time we discussed on virus...*	Original way of connecting the activity of building of mask to the ongoing pandemic.
	Experiment with Solutions	*So, I showed them both videos and I said '...Which of the experiment do you think will better help you understand or answer your questions'.*	Teacher experimenting with the release of teacher agency by allowing students to decide on the activity to facilitate their understanding.
Teacher Leadership	Coordination and Management	*Maybe we can split the area in two...one of us could teach one portion and then... cross-over ... and then in the end, it can just come together.*	Development of upcoming lessons between two teachers in the same class.
	Parent and Community Involvement	*I actually started off...something small that the kids need to pre-prepare before the lesson...*	Development of activity where parents are involved in knowledge building with their child.
	Contribution to the Profession of Teachers	*If lao shi (Chinese teacher) wants...she can use the left-hand side, the empty side to let them do a translation... So it's like a two-in-one English Chinese book...*	Teacher contributed by offering a strategy to increase the connection between lessons.

Conclusions and Future Work

This paper sought to demonstrate how a PLC, when infused with knowledge building principles and integrated with the Knowledge Forum, supported pre-school teachers in online professional development during HBL. This study has helped teachers within a community to explore ideas and the teachers were able to also explore their individual roles as knowledge builders. We were able to conduct analysis of data extracted from the classroom lessons, school's PLC sessions, and KF posts, and proposed a new framework for professional teaching practice, based on adaptations from prior coding schemes. The results from this study has shown that knowledge building aided a shift to higher scales for components of professional teaching practice, such as teacher's adaptability, design thinking and certain aspects of leadership and collaboration. These components also helped enhance a teacher's professional development, especially during crises such as a pandemic, where teachers are forced to alter their practice within short timeframes.

A possible explanation for the initiative's success may be due to the reduced face-to-face interaction with students. Before the pandemic, teachers had the luxury to manage happenings in the classroom. However, with such direct interactions taken away, teachers had to rely more on connecting with parents during the online lessons, and so teachers were more attentive to their students' ideas. Therefore, the teachers had to be more adaptable to feedback given and engaged in design thinking to solve problems that arose. Furthermore, teachers used the weekly meetings to update the other teachers on their progress and to seek advice on how to facilitate advancement of knowledge in the classroom. Thus, the teachers' professional development was enhanced during Home-Based Learning. To ensure that the teachers' professional development can be continued and further improved using knowledge building, future avenues of research will include comparisons of the maintenance of teachers' professional development, between schools that are engaged in knowledge building and schools that implement other forms of strategies and pedagogies.

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A case study of emotion analysis for collective idea improvement

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Abstract: Although it is common to recognize the importance of emotional regulation in computer-supported collaborative learning, few studies have examined the development of emotional regulation in Knowledge-Building (KB) discourse. This paper reports on the students' emotions analyzed using automated detection while they engage in collective idea improvement. Data was taken from Students' KB Design Studio (2019), a two-day workshop attended by 37 students to tackle the real-world problem of sustainable food source. Using a multimodal approach, we analyzed a group of five students' face-to-face and online discourse; their emotions from video data; and their self-reported emotions at different points of the day. We found the group's face-to-face discussion comprised mainly of idea-sharing and brief suggestions for their prototype features such as fact-seeking questions and unelaborated explanations. However, the automated software detection suggested that two students who engaged more in idea sharing expressed more occurrences of happy emotions. Of these two students, the one who reported moments of frustration seemed to contribute more complex ideas about the prototype on Knowledge Forum. Our findings warrant the need for more MMLA research to explore how different student emotions can play a positive role to support knowledge building.

Introduction

Research on affective learning suggests that the social component of learning such as student discussions may uniquely influence students' emotional responses and subsequent engagement (Linnenbrink-Garcia, Rogat, & Koskey, 2011). For example, students can display affective reactions when they negotiate meaning in small group social interactions and subsequently influencing their choice to engage or disengage in the learning. Such affective reactions can also be richly present in collective idea improvement in Knowledge Building environments. For instance, a student who comes across an idea of interest may express curiosity while another student who has made a note contribution may express joy. Examining students' emotions in idea improvement offer an understanding of their cognitive activities and engagement as well as their emotional regulation as they work collectively towards knowledge advancement. Currently, literature focusing on students' emotions in relation to their learning in KB is thin (Zhu et al., 2019). This paper attempts to contribute to this understanding by reporting findings on students' emotion in relation to KB process from their face-to-face and online discourse in a unique out-of-school knowledge building environment.

Students' socio-cognitive dynamics in Knowledge Building

Knowledge building approach to learning positions students as agents of learning in an environment that focuses on collective idea growth. In a Knowledge Building environment, students work as a community, they constantly share, inquire and build on each other's ideas to bring about idea improvement and to advance community understanding and knowledge (Scardamalia, 2002). The last decade has seen much effort to understand and examine students' idea improvement in relation to depth of inquiry and understanding in terms of epistemic beliefs and knowledge (e.g. Chen, 2017; Lin & Chan, 2018; Zhang et al., 2010). For instance, Zhang and colleagues (2010) investigated elementary students' idea improvement based on the progression of depth of understanding and epistemic approach from students' questions and explanations in KF. They showed that students' engagement in idea improvement should generate more questions seeking for explanations of phenomena or inquiry as well as explanations elaborating reasons and relationships. Likewise, Lin and Chan (2018) showed that idea improvement can be understood by inquiry threads. They explored how elementary students deepened the inquiry and advanced knowledge as they contributed questions to sustain the inquiry discussion and explanations that supported deeper understanding of the issue at hand. More recently, there is increasing interest to explore the connection between student affective behaviors such as emotions or physiological responses with the learning processes of idea creation and improvement in group collaborations (e.g. Furuichi & Worsley, 2018; Zhu, et al., 2019).

According to studies on student emotions and academic performance, student emotions can positively or negatively influence achievements, motivation, attention and cognitive focus (e.g. Pekrun, 2000, 2017). For instance, it has been found that emotions such as enjoyment and pride can positively influence students' learning as compared to negative emotions such as boredom (Pekrun, 2000). However, negative emotions do not necessarily discourage learning and may even be an indicator of knowledge construction (e.g. D'Mello et al. 2014; Worsley & Blikstein, 2016). Thus, findings from existing research on emotional learning remained mixed. In addition, such studies have been mainly conducted on university students and little is known about primary and secondary students. Building on this understanding, we posit that students' emotion will affect their knowledge building work too. To our understanding, there has been only one recent study done on emotions in KB learning and work in this area is still largely underexplored in the KB classrooms. In the study, Zhu and colleagues examined grade 1 and 2 students' emotions from both online and face-to-face discourse in KB lessons. The researchers manually coded for emotions from classroom videos using speech emotion analysis and emotions from students' online discourse using sentiment analysis. They also coded for idea improvement (based on a set of idea improvement contribution types) from transcripts of classroom videos and online discourses using content analysis. The study found that emotions such as surprise, challenge, and neutrality can be beneficial as students who expressed these emotions tended to elaborate reasons, described relationship and mechanism surrounding ideas they explored. In addition, their work also highlighted that confusion can be an important predictor of affective states in students with high participation in collaborative discussion (Zhu et al., 2019). From this work, we can see that epistemic emotions which relate to knowledge and the generation of knowledge (Pekrun and Stephens, 2012) can emerge from knowledge building processes such as idea improvement. However, whether these emotions positively influence students' knowledge advancement warrants more research validation and investigation.

With advancements in multimodal learning analytics research, video analysis is increasingly adapted to detect students' emotions through their facial expression (e.g. Arroyo, et al., 2009; Bosch, et al., 2016; Truong et al., 2007). For instance, Arroyo and colleagues found that using sensors to detect students' affective states and facial detection software can predict more than 60% of the variance of students' emotional states, which fared better than predictions of emotions from other contextual variables from the instructor, when these sensors are absent. Likewise, Bosch et al., (2016) used FACET, a commercialized affect detection software to examine learning-centered affective states in a computer-enabled classroom. They reported that the webcams face-based detectors could provide automatic detection of boredom, confusion, delight, engagement, and frustration in natural learning environments. Thus, automated detection may be a feasible way forward to advance understanding of emotional learning in KB classrooms. In this study, we report a preliminary work to trial an automated detection system with 360 camera to explore students' emotions in relation to their engagement in idea improvement. By enhancing our understanding of the socio-emotional and socio-cognitive dynamics of student learning in KB, we aim to improve the quality of interactions for teachers and students in KB classroom as well as teachers' pedagogical knowledge of classroom discourse. For example, a teacher may tend to adopt guided inquiry in order to avoid student confusion, but may miss out what might be productive confusion that potentially lead students to delve deeper into the concept understanding. Furthermore, a more in-depth knowledge of socio-emotional and socio-cognitive developmental in children and adolescent can possibly shed new light on the design and implementation of knowledge building lessons.

Context

Data for this paper comes from the "Student Knowledge Building Design Studio (SKBDS)" which was a two-day (Twelve hours of engagement) workshop in which thirty-seven students from seven different schools came together to knowledge building on the real-world problem of sustainable living. Table 1 outlines the principle-based approach to designing the Design Studio. The workshop design planning was supported by KB principles such as Real ideas authentic problem, KB discourse, Idea improvement, Idea diversity, Rise above, Symmetrical advancement of knowledge. Briefly, students were introduced to sustainable farming and they conducted a series of KB discussion, experiments to investigate light and photosynthesis. Students then discussed and built the prototype for vertical farming. Students were engaged through various collaborative modes such as whole-class discussion, group work and discussions, KF discussions. The SKBDS was conducted in November 2019 and participated students had an opportunity to learn out of the boundary of a typical classroom setting and to give them opportunities to build knowledge in a vibrant and open community of learners. They had opportunities to interact with peers from other grade level and schools, as well as with teachers, researchers and scientists as they engage in idea improvement.

The unique design of SKBDS provided a specific context of KB learning for the purpose of this study. We recognized that not all occurrences showing epistemic emotions can be expected to have similar effects on learning. For example, a student may feel uncertainty during a lesson if his or her textbook was misplaced (before the lesson).

This affective behavior may be a distraction to the child and may or may not impact the child's learning process. To address such nuances and the complexity of emotions in learning, we have noted the importance of the contextualized instances of epistemic emotions with specific reference to learning or knowing activities. Furthermore, the same epistemic emotions detected may not produce the same impact on learning each time it is detected, as there may be both productive and negative epistemic emotions. Thus, the design studio promoted a KB learning environment to better allow us to explore such nuances and complex nature of epistemic emotions in relation to KB processes.

Table 1: Design Studio activities.

Design Principles	**Activities**	**Mode of engagement**	**Purpose of activity and alignment to KB principles**
Real ideas authentic problem: Supporting students to understand how a real scientific community work and think about real world problem. Supporting students to make connections to the problem that they have to tackle as a community. Symmetrical advancement of knowledge: Engaging students with experts in ways that allow students to understand their own contribution to the field. Shifting students from thinking that there is an expert-know-it-all view to a co-construction view of knowledge.	Students introduced to the big problem of sustainability cities and communities, leading to sustainable farming. Engagement with real Scientist: How do scientists respond to problems in the real world? How do scientists improve ideas?	Whole-Class Discussion Initial small group KB talk to generate ideas about sustainable living.	How do an innovator, scientist or designer think? Students to appreciate the idea improvement process embarked by innovators and scientists and that the path of problem solving is not linear.
KB discourse: Initiating students into a culture of discourse and collaboration at the start of the design studio, rather than following a regular classroom practice to focus on individual growth.	Whole-class: Discussion with expert scientists and researchers.	Whole-Class talk	Understanding the path of creative work with ideas. Students to identify with the real-world problem of sustainable living. How do we contribute? What does it take to improve ideas and make it work in the real world?
Idea improvement: Ensuring students have opportunities to continuously improve the quality, coherence and utility of ideas.	Design experiments: Series of hands-on experiments on properties of light.	Group work	Investigating the science and engineering aspects (e.g. photosynthesis; structural stability) necessary for the design of a vertical farming system. Students recorded their ideas, findings, questions and discussion on paper and KF.
Idea diversity: Helping students to understand how ideas expand – including contrasting ideas. Supporting students to go beyond a topic/the discipline to the present state and growing edge of knowledge in the field.	Students think about creation of a new farming system that covers the plants' nutritional needs, enable optimal growth of the plants and yet save space? Students collect useful information from articles provided to design a prototype system that can provide ensure high/ maximal rate of photosynthesis. Students produce detailed sketches and descriptions of their prototype and some of its unique features.	Group work	Constantly exploring diverse ideas and design of vertical farming prototype. Research: Students constructively use authoritative sources to inform their design. Students engage in KB discourse (small group, whole class, with experts, with researchers) to generate and put ideas together for prototype design.
Rise above: Promoting students' creative knowledge building by challenging them towards higher-level forms of problems. It means supporting students to learn to work with diversity, complexity, and messiness and moving to higher planes of understanding,	Translating ideas to concrete prototype: Students build their prototype and discuss on prototype improvement. Students present their work to the community. Group present ideas and prototype to one another.	Group work Whole-class discussion; connecting with community and expert scientists.	Improving on idea through prototype building, sharing and assessment. Engaging students in symmetrical knowledge advancement and Rise above.

	Scientists/teachers take on a discussant role instead of a judge role.		

Methodology and analysis

This case study explored multimodal data analysis and the use of multimodal learning analytics by incorporating software detection to examine students' affective engagement in relation to idea improvement. A mixed method research design was used incorporating multimodal learning analytics on facial expression analysis, idea improvement analysis, and student self-reports. These analyses serve to answer the following research questions: (1) To what extent can we characterize students' emotions in relation to idea improvement? (2) How accurate are the machine analysis in these emotion analysis? As shown in Table 2, we examined students' idea improvement from both their textual KF discussion and their verbal discourse from face-to-face discussion. Using video recordings of student discourse, we explored corresponding students' affective engagement by analysing emotions from their facial expression with an automated detection software. The emotion analysis was supported by self-reports generated through an emotional survey. Although we also collected students' physiological data from empatica, however, due to the large datasets involved, we focused this paper on the automated analysis of student emotions from a short 360 video footage from a group of students in relation to their idea improvement processes from their face-to-face discourse.

Table 2: Multimodal data collection.

Dimension	Modality	Data Sources	Data Analysis
Students' idea improvement	Textual	Student KF notes	Text analysis
	Verbal	Audio recording of students' face-to-face discussion	Content analysis
Students' affective engagement	Socio-emotional	Video recording of student facial expressions	Video analysis (manual and machine)
		Student self-report	Survey analysis
	Physiological	Empatica wearable	Physiological data using Empatica software (not included in this paper)

Figure 1 briefly illustrates our setup which involved the use of 360 camera and frontal camera to obtain close up capturing of facial expression of every student in the group as well as their actions and discussions. Lapel microphones were attached to individual students to obtain a clearer recording of their voices. The design studio involved a total of 6 student groups (5 to 6 students in a group seated around a common table). The 360 camera setup was trialed with 3 groups. All the students also completed an emotional-survey at different time interval of the Design Studio. The survey included the following ten items on a likert scale: (i) I am good at this; (ii) I feel challenged; (iii) I feel frustrated; (iv) I am learning; (v) I am feeling happy…sad; (vi) I am feeling irritated; (vii) I am feeling cooperative; (viii) I am interested; (ix) I am involved; (x) I am thinking. Students were paused at 8 intervals (points) on Day 1 and 6 intervals (points) on Day 2 and given few minutes to respond quickly to the emotion survey.

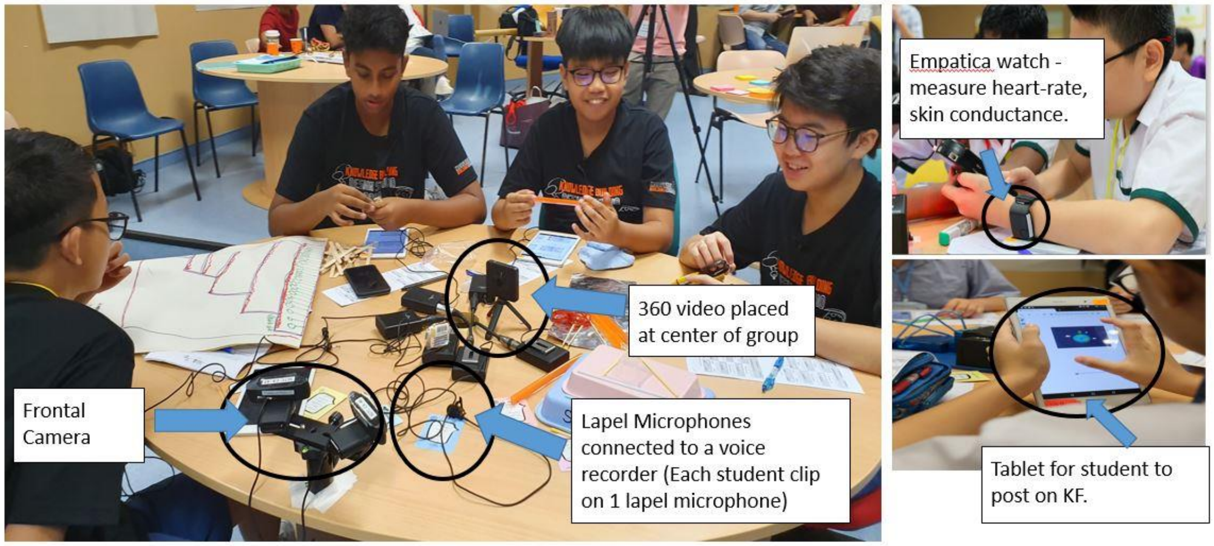


Figure 1. Setup of equipment to capture multimodal data.

Coding students' idea improvement

Based on theory building moves suggested by Zhang et al. (2018), we coded students' contributions in both face-to-face discussion and KF discussion for idea improvement. We analysed their ideas in terms of the quality of questions and explanations. In terms of questions, we coded fact-seeking question that only required basic factual responses or an explanation-seeking question that required elaboration on mechanisms and causal relationships. In terms of explanations, we coded simple (unelaborated) explanation such as giving a short opinion to an elaborated explanation that mentioned reasons and mechanisms with sound scientific understanding. Table 3 illustrates these codes and sample examples.

Table 3: Coding scheme for idea improvement

Contributions to idea improvement	Description	Sample coding (examples from KF and face-to-face discussion)
Asking a fact seeking question	Questions on the definition of terms or concepts, or seeking factual information	"you mean like two sides or what?"
Asking a explanation seeking question	Questions seeking open-ended responses with elaborative explanations	"so if it's inside the (building) how the solar panel receives light?"
Providing a simple explanation	Opinions without any elaboration or justification, indicating shared or different opinions or understanding, a restatement of the previous idea	"then make it waterproof" Saves more space than if there was a dedicated building
Providing a partially elaborated explanation	Expressing alternative ideas with partial explanations; requesting the previous author to elaborate; adding details to previous ideas. The explanations may include some misunderstanding.	"let's say the rooftop is like this right, then open, then there is some like latch that you can just hang over the=" We used solar energy as a main source of energy for our farm and wind energy as a secondary source of energy we decided to use this two energy as they are sustainable
Providing an elaborated explanation	Reasons, relationships or mechanisms elaborated. The explanations are scientific	Battery is used to store the excess energy produced from the solar panel and windmill so that minimal energy is wasted and the energy can be used during emergencies.

Machine analysis of students' emotions

We applied an automated detection software to analyse students' emotions from their videos. This research purpose software was developed by our collaborators from Panasonic Industrial Devices Singapore. Called the "Human Sensing Software", this software has been configured to measure 7 basic emotions labels including: Neutral, Fear, Disgust, Happy, Sad, Angry, Neutral. Figure 2 shows the detection of some of these expressions from student faces from video data. The software analysed movement of eyebrows, eyes, mouth, cheeks and face to match to the basic emotion labels. Based on a 30 frames per second (fps) analysis, the software outputs the average of the emotions detected per second for each face that appeared in the video. Detection accuracy with testing datasets (5545 images with 14 subjects) averaged at 81.45% with the highest (94%) for "happy" emotion and lowest (66%) for "sad" emotion. To ensure reliability of the software for this study, we conducted manual coding with the same framing as the machine to access the accuracy and usefulness of the machine analytics.

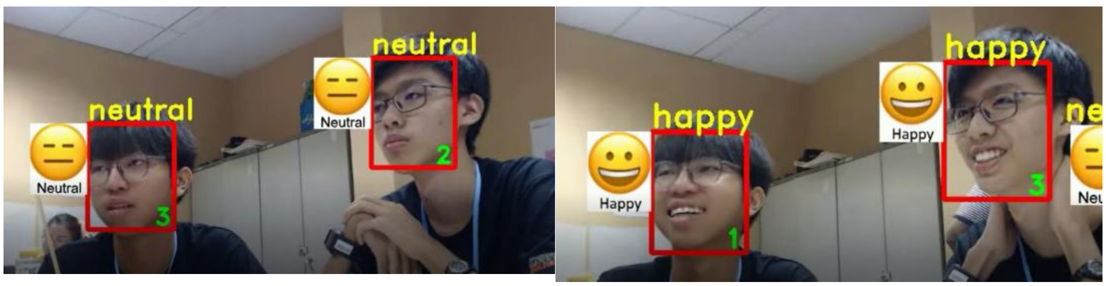


Figure 2. Sample of Happy emotion and Neutral emotion detected from machine.

Key findings

We present four key findings based on the detailed analyses of two students out of the five students in Group 6 (S6-1; S6-5) at the SKBDS.

Group discussion on Knowledge Forum more intense than face-to-face interaction

The group' idea improvement appeared more evident from their online discussion in a KF view "Group 6 Idea Journey". The group posted a total of 15 notes into the view. As illustrated below, students' posts in KF reflected a higher proportion of partially elaborated explanations and elaborated explanations (Figure 3) compared to their contributions in face-to-face discussion (Figure 4).

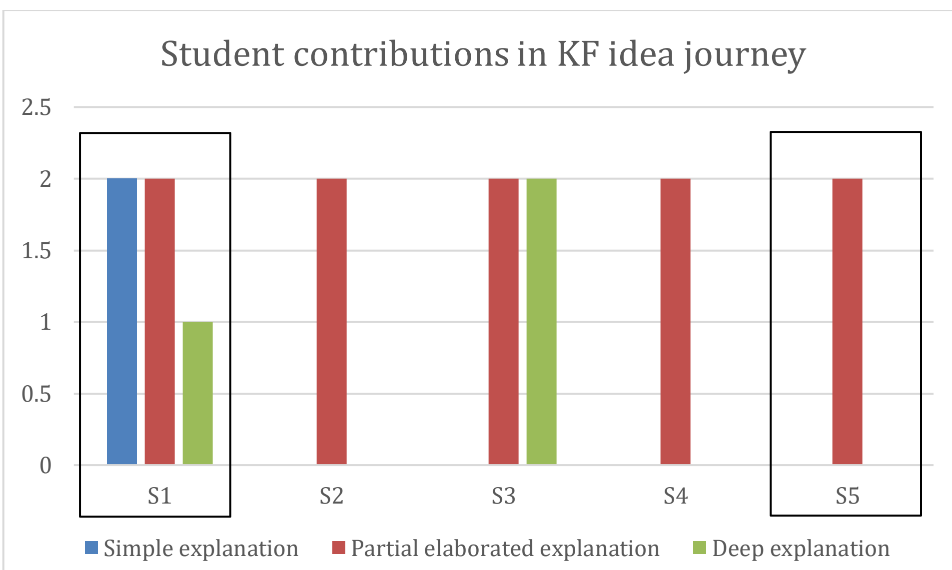


Figure 3. Contributions of ideas in Group 6 idea journey view

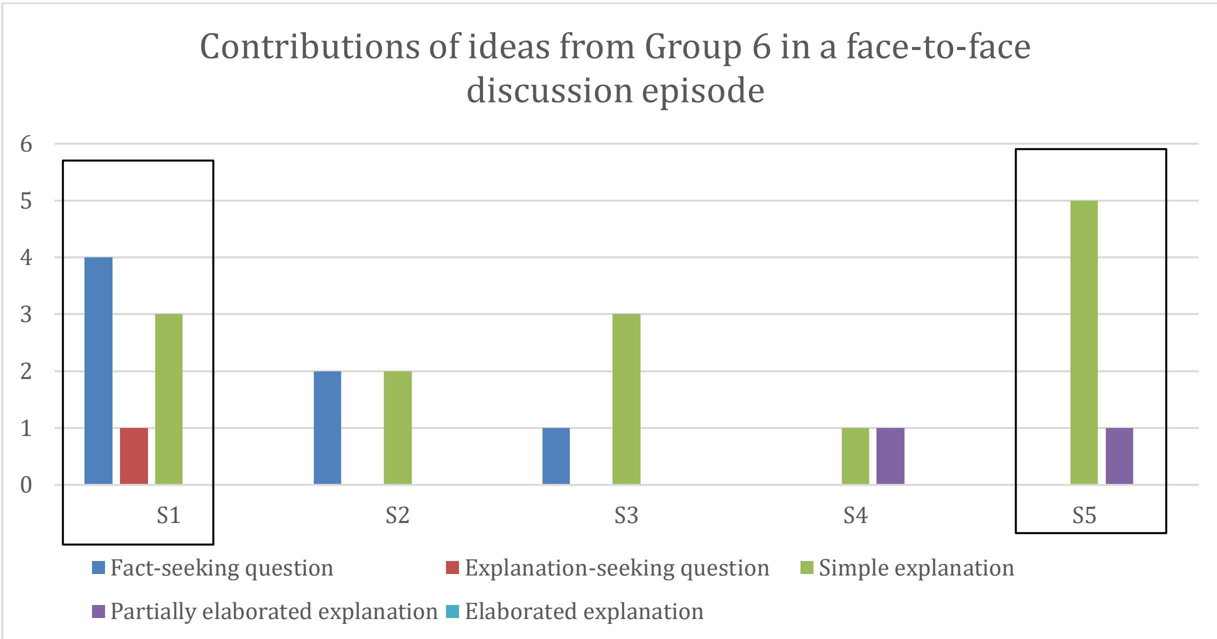


Figure 4. Contributions of ideas from Group 6 in a face-to-face discussion episode

Their notes showed additional information for understanding the prototype features such as battery and dome as well as some reasons or relationships for these ideas, as illustrated in Table 4. Compared to their contributions in the face-to-face discussion episode shown in Table 5, students' discussion in KF appears more intense. Notably, the analysis also suggested that the students, particularly student 1 (S1 or G6-1) who contributed 5 notes of the 15, contributed elaborated explanations on the prototype idea and asked question to engage in further idea improvement.

Table 4. Examples of students' elaborated explanations of their prototype design.

No	Title	Student	Content	Type of contribution
1	Water tank + funnel	S1	Independent source of water which is collected from the rain When there is insufficient water due to dry spells, water is obtained from pub tap which is connected Water is constantly recycled in this way	Partially elaborated explanation
2	Battery	S3	Battery is used to store the excess energy produced from the solar panel and windmill so that minimal energy is wasted and the energy can be used during emergencies.	Elaborated explanation
3	Our favourite part	S1	Our favourite part is the retractable dome. It is able to reflect light back to the plants and we really like the concept behind it. We like that we are combining both nature and technology to solve our problems in our own way. The shape also reflects light in random directions instead of straight back, distributing it evenly. To solve certain problems which may come, such as a possible disease infecting the plants, we suggest regular checkups by experts on the wellbeing of the plants.	Elaborated explanation
4	Dome	S3	The dome is at the top of the structure, which is retractable. It is opened during the day and closed at night to prevent light pollution and not let light within escape and go to waste.	Elaborated explanation

Table 5. Illustration of students' contributions in face-to-face discussion.

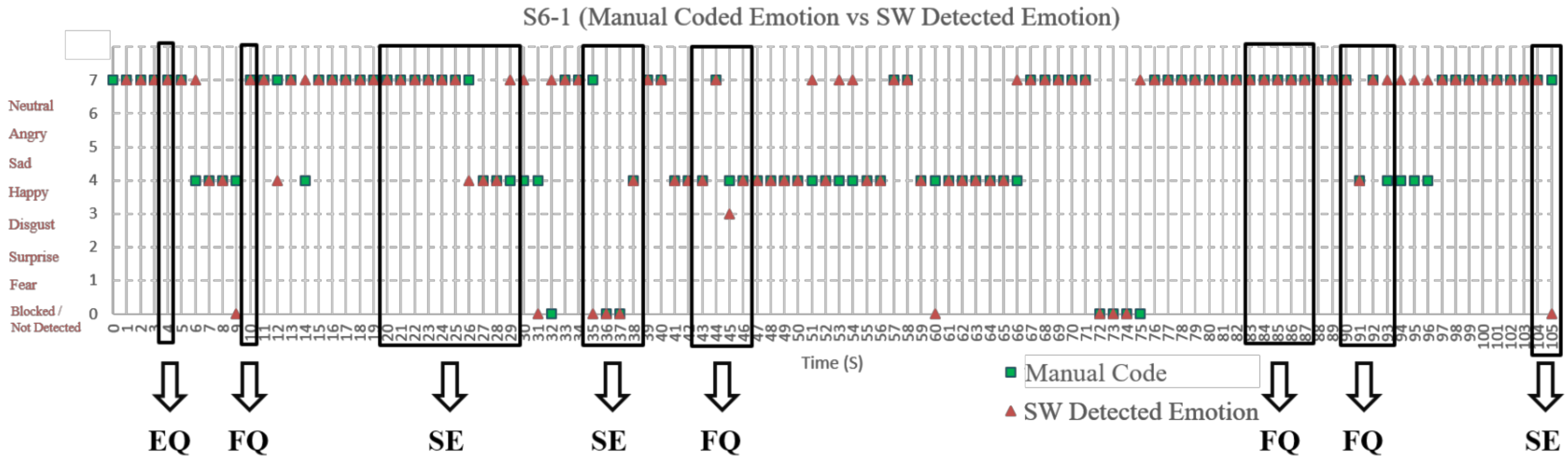
Time	Speaker	Content	Type of contribution
00:01:23	S1	solar panel can be waterproof or not?	Fact-seeking question
00:01:27	S5	yah easily waterproof	Simple explanation
00:01:30	S1	cause raining, (what if it rains)	Fact-seeking question
00:01:35	S3	then make it waterproof lah	Simple explanation
00:01:37	S4	I thought it's already waterproof	Simple explanation
00:01:39	S3	yah=	
00:01:39	S5	cause it is already water proof	Simple explanation
00:01:40	S3	it's already waterproof?	Fact-seeking question
00:01:42	T	cause if it's already waterproof the we can=	
00:01:44	S1	if it doesn't work then the windmill will take over	Simple explanation

Differences between students in contributions in face-to-face discussion (S6-1 more probing than S6-5)

When we studied a short two minutes segment of the group's face-to-face discussion on day 2, the discussion pattern inclined toward idea sharing as students mainly posed asking fact-seeking questions such as position of a solar panel and they contributed brief and unelaborated explanations such as whether solar panel was waterproof (Table 5). Notably, student 1 and student 5 (S5 or G6-5) appeared to contribute more to this discussion (Figure 3), one of students (S1) was consistent to the analysis on knowledge forum. Specifically, S1 asked questions in relation to positioning the solar panel and the function of a dome. While S5 provided suggestions such as placing the solar panel inside a dome and using sensor to activate the opening and closing of the dome. Student 3 and 4 were observed to be working on prototype building at times.

Similar expressions in both S6-1 and S6-5 from machine analysis of facial expression

Machine analysis of these two students (S1 and S5) showed that S1 displayed "happy" emotions in two occurrences of asking fact-seeking questions and providing simple explanations (see SW detected label in Figure 5a and 5b). Likewise, S5 displayed "happy" emotions in three occurrences of asking fact-seeking questions. However, neutral emotion does not mean that students were not engaged. Take S1 for instance, at the timestamp of 00:00:04, the machine detected neutral emotion when the student was asking an explanation-seeking question "so if it's inside the (building) how the solar panel receives light?" Similarly for S5, at the timestamp of 00:00:29 to 00:00:35, the machine also detected neutral emotion when student 5 was providing a partially elaborated explanation to explain the use of a daylight sensor. A researcher performed manual coding to check and validate these emotions detected from the machine (see manual label in Figure 5a and 5b). The results showed high correspondence in happy and neutral emotions but no validation for machine detection of sad, disgust and angry from the two students.



FQ – Fact-seeking question; EQ – Explanation-seeking question; SE – Simple explanation; PE – Partially elaborated explanation; Elaborated explanation

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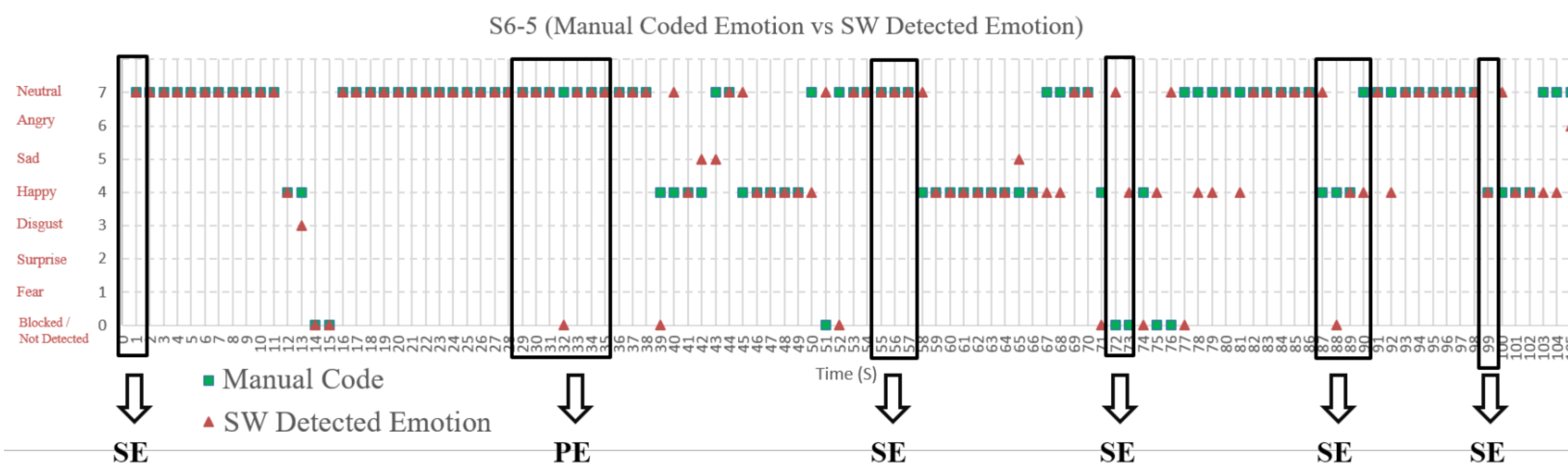

FQ – Fact-seeking question; EQ – Explanation-seeking question; SE – Simple explanation; PE – Partially elaborated explanation; Elaborated explanation

Figure 5a & 5b: Video analysis of students' emotions in illustrated episode (Top: Student 1; Bottom - Student 5)

Self-reporting emotion survey at 14 points throughout the two-days engagement

When triangulated with students' self-reports from the emotional survey on both days, we found a distinct difference in their rating on frustration on both days between the two students as shown in Figure 6. The findings from other items in self-report such as "feeling challenged", "feeling that I have learned", "feeling cooperative, "feeling irritated" and "feeling interested" were found to be almost comparable between the two students.

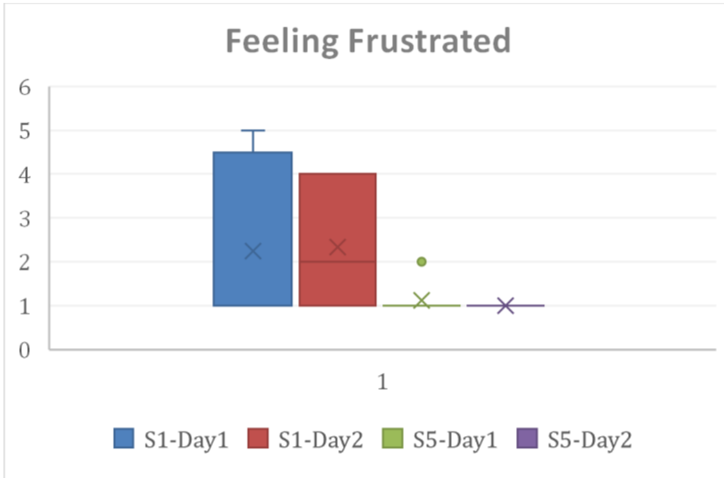

Figure 6. Difference in Frustration level between S1 and S5 from self reports.

Discussion and implications

MMLA represents a way forward to further understand students' emotional learning in KB. Although findings were based on a very short episode, the automated detection illuminated different student emotions as they engaged in idea sharing and construction. For instance, students who actively contributed questions and explanations to improve the group idea displayed higher occurrences of joy and neutrality, a finding that concurred with that reported by Zhu et al. (2019) on positive emotive indicators of students' idea improvement. However, more work is needed to understand these correlations, as we also found occurrences of joy and neutrality when students were not contributing to the idea improvement. Furthermore, ongoing work is also needed to understand other emotions. The software also detected emotions of sad, angry and disgust but manual cross-checking done by a researcher validated only neutral and happy. The accuracy between manual and machine coding is 60% to 70% which leaves much space for improvement before such emotion analysis can be made useful to teachers in their day-to-day practice. The difficulty in levelling up the accuracy of machine learning is increased significantly in an authentic knowledge building, collaborative learning situation where students are able to interact with other students and teachers and freely move around to build prototypes, to scribe ideas on papers and worked on their computers. The tracking functions in these cameras were unable to capture students' facial expression when they move around in a robust learning environment.

The nuances revealed from our analyses corroborate with earlier research on the productive interaction of emotions such as confusion or frustration with learning (Zhu et al., 2019), especially when these emotions that are usually deemed undesirable by teachers. In this study, we found that student S1 who reflected a significant level of frustration in his self-reporting survey was shown to have a higher participation rate on KF and face-to-face discussion. From his contributions, he appeared to be the most active (out of the five students) in advancing the group prototype idea. It is therefore essential to calibrate our machine analysis to increase its sensitivity to detect these "important" emotions that can challenge teachers' perception of students' engagement and interest in the topic. Lastly, our findings are not generalizable across groups and may not be representative of typical student participation in face-to-face discussion within the group. However, the short video data analysis provided a case for support to argue that idea improvement in KB requires emotional regulation. Ongoing work involves exploring relationships between student emotions with other types of discourse moves such as reasoning, reflecting or synthesizing ideas which may indicate students' collective idea building as well as data triangulation based on other data sources such as physiological data to validate different student emotions.

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Tracing a Teacher's Reflective Noticing and Scaffolding of Student Inquiry in Grade 5 Knowledge Building Communities

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Abstract: This study provides a precise tracing of how a teacher engaged in student-centered reflective noticing and envisioning to facilitate yearlong scientific inquiry in two grade 5 knowledge building communities. On a weekly basis, the teacher updated a reflective journal in which she recorded her noticing of students' ideas, connection, and inquiry needs, interpreted pedagogical meanings, and envisioned strategic moves to foster students' sustained inquiry. Qualitative analysis of her journals identified seven themes of reflective noticing and scaffolding, her reflection flow, and outstanding scenarios. These core patterns of noticing further informed the teacher's pedagogical thinking and ongoing envisioning in order to provide responsive scaffolding. Her focus on reflective envisioning changed in line with students' needs.

Introduction

Research in the learning sciences has produced solid advances in understanding how students engage in joint problem solving and collaborative discourse to build deep knowledge supported by technology-based learning environments. Researchers have developed various collaborative, inquiry-based learning programs with effective learning outcomes in light of these advances. However, despite the research advances, the field still confronts the challenge of how to implement and sustain the new learning models in broad classrooms to transform educational practice. A critical issue underlying this challenge pertains to the new role of teachers in student-driven collaborative knowledge building. Although existing research highlights the original roles of the teacher as a co-learner in students' inquiry deepening progress (Tabak & Baumgartner, 2004; Zhang, Tao, Chen, Sun, Judson, & Naqvi, 2018), it remains unclear how the teacher may play out such roles to engage effectively and nurture his/her students' efforts for sustained, creative inquiry. This study provides a detailed tracing of how a teacher engaged in student-centered reflective noticing and envisioning to facilitate yearlong scientific inquiry in two grade 5 classrooms.

The inquiry-based practices analyzed in this study were designed based on the Knowledge Building (KB) pedagogy, which aims to transform classrooms into authentic knowledge building communities where students "produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community" (Scardamalia & Bereiter, 2010, p. 80). Teachers in the KB contexts engage in reflective and adaptive practices (Zhang, Hong, Scardamalia, Toe, & Morley, 2011). They engaged in students' ongoing inquiry and iteratively re-design customized pedagogy for enhancing students' collective idea progress (Sergis & Sampson, 2017). Their deep reflection builds insights for their professional development (Zeichner & Liston, 1996) as well as students' learning (Brookfield, 2017). The genuine implication of teachers' reflection ties with the subsequent action (Shulman, 1987), dealing with complicated and uncertain situations (Schön, 1983) to ultimately advance their instruction in practice for improving students' knowledge. Throughout the critically introspective examination of own instruction and students' idea progress, teachers find ways to resolve the complicated problems in the classroom (Dewey, 1933) and fuel the learning milieu with unceasing inquiry and resilience to the changes in the classroom (Brookfield, 2017).

In order to facilitate students' collective knowledge building, teachers engage in open-ended planning and co-engage with their students in the inquiry process to catalyze productive knowledge building moves. As an important aspect of their teaching, teachers engage in reflective noticing and ongoing envisioning, to notice students' emergent inquiry and deeply muse on that moment to envision responsive moves to foster students' deeper inquiry (Judson, 2016; Hammer & van Zee, 2006; Robertson, Atkins, Levin, & Richards, 2016). In light of the previous literature, we identified three interconnected elements of teachers' reflective noticing and envisioning in students' collaborative inquiry-centered learning: *Attend*, *Interpret*, and *Make Moves* (A-I-M, Zhang, 2019). That is, teachers notice students' individual and collective inquiry, reflect on the noticed moments, and envision and plan the following lessons for facilitating students' inquiry progress.

The current study was conducted to provide a comprehensive account of the ongoing reflective noticing and envisioning of a grade 5 teacher to facilitate yearlong scientific inquiry. The research questions address: a) How did the teacher attend to and reflect on students' ongoing inquiry on a weekly basis to envision opportunities to foster deeper knowledge building among students?; and b) What types of flow and scenarios did the teacher's reflective envisioning follow to address emergent classroom needs?

Research Context and Methodology

Classroom Context

This study investigates a teacher's concurrent reflection and envisioning two grade 5 science classrooms with 42 students in KB pedagogy in 2015-2016. At the beginning of the school year, students in the classrooms started with exploratory activities to bring initial inquiry about the human body system. While collaborating, they deepened knowledge about their interests and created new inquiries to improve a wider range of ideas. They developed their ideas during a metacognitive meeting (MM) that is an interactive conversation to build on theory with each other. They also generated inquiry and built on peers' ideas on a virtual discussion platform, Knowledge Forum (KF).

Two teachers participated in the whole project, and the present paper focuses on one (Mrs. G). Mrs. G monitored the progression of students' ideas, theories, and inquiries on KF and in MMs. In order to record her reflection and envisioning of students' knowledge building process, she kept reflective journals in her homeroom class and Mrs. W's class every week. She wrote her observations and reflections on the students' idea progress and scaffolded follow-up lessons to improve the students' collective knowledge building using a table that has three columns in order: *I notice……*, *I think……*, and *In the coming week*, *we may…….* This format was outlined based on the idea that reflective teachers noticing and envisioning in students' thinking (Jacobs et al., 2010; van Es, 2011), which is further identified A-I-M framework (Zhang, 2019) that consists of the three interconnected elements (Attend, Interpret, and Make Moves, in order) of teacher noticing and scaffolding. A total of 27 reflective journals were collected from the two classrooms.

Data Sources and Analysis

The primary dataset for the present study is the teacher's reflective journals. For the analysis, 172 sets of Attend, Interpret, and Make Moves (A-I-M) columns from the collected reflective journals were arranged chronologically in a row in Excel format. Conducting the grounded theory approach (Strauss & Corbin, 1998), the two authors of this research discussed the qualitative data analysis process a number of times and reached a satisfactory agreement of the patterns of teachers' reflection with overarching themes. The initial analysis examined the teacher's reflective notes in A-I-M in the columns. After the initial analysis, the authors felt the need to classify the analysis unit of A-I-M more specifically. For instance, in the Attend column, sometimes the teacher attended to students' learning and interpreted what she noticed simultaneously. Thus, each stage of Attend, Interpret, and Make Moves, respectively, was segmented into smaller A-I-M to investigate the teacher's reflection flow more sophisticatedly. The outstanding scenarios were also identified by re-reading and qualitatively tracking the teacher's reflective notes in Interpret and Make Moves columns, following the notes in Attend columns. After three more turns of carefully re-reading the data and matching that with the coding result for iteratively revising it, the final coding book was built (also see Park & Zhang, 2020, which investigated teachers' reflective journals of a different school year). We found interesting results of tracing the teacher's focus of noticing and envisioning, segmented A-I-M, and critical scenarios, which will be reported in this paper. The coding result will be presented in the following section below as a summary and detailed description.

Findings

Teacher's Reflection and Envisioning in Students' Knowledge Building

The analysis result of teacher's reflective journals revealed seven overarching themes across teacher's A-I-M—idea progress (students' individual and collective focal inquiry), collaboration, students' need/intent/emotion, supportive materials/tools, KB practices and norms, teacher's intent/emotion, and tracking students' ideas. Overall, the teacher took notice of students' idea progress, students' need/intent/emotion, and use/creation of supportive materials/tools the most throughout the reflective envisioning process. She increasingly focused on her own intent and emotion in Interpret and envisioned tracking students' idea progress in Make Move. The cases of *skip* that teacher did not write about her reflection or envisioning increased in Interpret and Make Move than in Attend. The detailed descriptions of coding categories are presented in the following sections.

Attend

The teacher noticed and reflected on not only students' important moments of collective knowledge building using necessary sources but also the teacher's own support for their learning progress. She recognized individual and collective students' emergent and expanded inquiry and asked them follow-up questions. She found students' shallow ideas, misunderstanding, or static idea progress and spotted students who had a deep knowledge of certain topics. She carefully noticed students' needs and emotion and their use or creation of supportive materials and tools. Also, she found a lack of keeping class norms and felt stunned or struggled by students' idea progress and attitude (see Appendix A).

Interpret

The teacher continued monitoring students' learning progress and reflecting on the meaning and reason behind what she noticed and her own support for students' learning. In particular, she reflected on new inquiry, emergent connections between diverse concepts, and expansion of the community's discussion topics, which all was to be improved aligned with classroom activity to deepen collective knowledge. She wondered about the reason behind students' thinking flow and felt the need for facilitating students' idea progress and collaboration, especially by matching students who were researching adjacent concepts. Her reflection on facilitating students' learning also followed their real and urgent needs and growing motivation to work with peers. She felt that students needed to understand their responsibility to devote the best knowledge to the community, keep decent class norms, and use supportive tools with a clear purpose of advancing the community's knowledge. During her reflection, the teacher increasingly introspected about her own knowledge and instruction as well as stunning or struggling moments of students' progress and attitude (see Appendix B).

Make Moves

The teacher mostly envisioned her support and instruction to facilitate students' knowledge building, while she still recalled and reflected on students' expression of their growing enlightenment and motivation for learning with peers. She planned an advanced strategy to facilitate students' best and deepening inquiry but leverage their idea progress with each other. She also envisioned highlighting emergent and deep theory with meaningful use of supportive tools to build their collaborative knowledge. In order to meet students' positive learning intent and improve better class norms, she planned to provide students with adequate help and had a conversation with them in class or on KF accordingly. Moreover, she referenced her co-teacher's envisioning and planned to build on students' KF notes. While envisioning her better pedagogy, she felt the need to track students' emergent ideas that can be a big inquiry of the community and have effective ways of facilitating students' and her idea tracking process (see Appendix C).

Flow of Segmented Reflective Envisioning

What was further found from tracing the teacher's segmented A-I-M was that the three phases of the teacher's noticing, interpreting, and envisioning did not always happen in order; rather, she sometimes conducted two or three phases simultaneously, even in reverse order. Consequently, the teacher mostly focused on attending, interpreting, and making moves in each matched big phase. Nonetheless, interesting patterns were found that she deeply interpreted important moments of her attending to student's learning concurrently (A-I), interpreted student's knowledge building as envisioning how to facilitate student's collective progress (I-M), and did envisioning first and then interpreting student's important moment related to her envisioning (M-I). Examples extracted from the teacher's reflective journals are presented below in [1], [2], [3], sequentially. A-I mostly happened in the big Attend phase, while I-M and M-I occurred in big M frequently.

[1] **(A-I)** *S1 seemed to be just playing around, so I sat close by...... Then, he had an AHA moment CELLS DIVIDE and THAT is what makes things GROW!!!*

[2] **(I-M)** *I think there is too much belief that specific people OWN ideas...... why is this? I so want the shift to COLLECTIVE responsibility and desire to share, but that competitive world of learning is a hard shift.*

[3] **(M-I)** *I will talk with them to find out what knowledge they need to share and help them find a better place to connect...... I am thinking they are talking about white blood cells fighting infection...... so this ought to be in a different view.*

Critical KB Scenarios of Reflective Envisioning

Six outstanding scenarios were found by qualitatively tracing the teacher's reflective envisioning and scaffolding of students' knowledge building after noticing process (see Table 1). The teacher captured crucial moments of students' deep and emergent inquiry, lack of progress, collaboration, class norms, motivation and intent, and use of supportive tools. She focused on new directions of inquiry and missing connection between students' inquiries. She envisioned students' moves in efforts to leverage as well as advance the sustained progress of the community's inquiry by facilitating collaboration between students in need and knowledgeable students, with needing a timely track of idea progress. At the same time, the teacher's scaffolding was to maintain students' high motivation and responsibility to build KB class norms and use authoritative tools for collective idea progress.

Table 1: Critical KB scenarios of teachers' reflective envisioning according to students' progress

KB scenario	Attend	Interpret and Make Move
Scenario 1	Students are making progress with an area of inquiry, having deep ideas and emergent area/direction.	· The teacher thinks the need to facilitate emergent areas aligned with the community's progress and clarify students' new misunderstanding. · Typical reflective moves include highlighting/linking emergent directions with the community to co-design the next steps in class or KF and having a face-to-face talk with students to provide support.
Scenario 2	Students have been working on an area but are stuck with a lack of progress and deep understanding.	· The teacher thinks of students' best knowledge and high responsibility for clarifying and deepening ideas. · Typical reflective moves include having a face-to-face talk with students, promoting positive motivation and responsibility for making progress, and matching knowledgeable students with students in need.
Scenario 3	Students have collaborated with peers on an area of inquiry.	· The teacher thinks of building deeper and more connected knowledge by learning from knowledgeable students with high motivation. · Typical reflective moves include enhancing effective tracking of collective ideas and highlighting emergent ideas with the whole community to leverage the collective progress as meeting students' learning needs.
Scenario 4	Students have read and written KF notes without deep ideas, and the teacher discovered the need for improving class norms.	· The teacher thinks about the need for improving class norms and facilitating students' deep and collective ideas. · Typical reflective moves include highlighting important class norms with the community as meeting students' learning needs.
Scenario 5	Students have the motivation or need help to make progress.	· The teacher thinks about the need and reason for facilitating idea progress and collaboration, using useful tools and class norms. · Typical reflective moves include tracking and facilitating idea progress as meeting students' needs and using useful tools.
Scenario 6	Students have used supportive tools and created materials either individually or in groups.	· The teacher thinks about the need for using tools with a clear purpose for collective idea progress. · Typical reflective moves include facilitating purposeful use of tools for collective idea progress as meeting students' learning needs.

Conclusion and Discussion

The present study traced a teacher's concurrent reflective noticing and scaffolding of grade 5 students' knowledge building community. While the teacher cyclically reflected on students' progressive learning and designed the next moves, she followed seven patterns: idea progress, collaboration, student' need/intent/emotion, supportive materials/tools, KB practices and norms, teacher's intent/emotion, and tracking student' ideas. The teacher iteratively mediated on critical moments of students' idea progress with its reason, which informed the teacher's pedagogical thinking and ongoing envisioning to provide responsive scaffolding. The teacher's reflective envisioning was conducted in a dynamic and sophisticated way rather than in a linear sequence. Notably, her interpretation of students' knowledge building tended to be synchronized with noticing moments to picture the follow-up instruction in line with students' needs. During this process, she reflected on students' and her pedagogical intent at the same time and needed to track students' dynamic progress more effectively.

This study aimed to understand a primary school teacher's complicated thinking process in her responsive scaffolding of students' collective knowledge building. Reflective teachers are proactive in challenging the issues raised in the classroom from diverse perspectives with high responsibility and expertise in practice. Their reflective teaching is facilitated based on their deep meditation on hands-on experiences of teaching, from which they attain insights for their professional improvement (Zeichner & Liston, 1996) and for enhancing students' learning (Brookfield, 2017) by often further sharing their reflective noticing and thinking with students engaged in collaborative decision making (Zhang & Messina, 2010). Teachers' participatory pattern in student-driven collaborative idea progress (Scardamalia & Bereiter, 2010) is dynamic in that they consider diverse aspects of pedagogy and students' progress concurrently. Moreover, their responsive envisioning pattern is complicated since their thinking flows back and forth across classroom events of the past, the present, and the future. They do timely reflection while observing students' learning and designing students' more in-depth inquiry and join students' progress as co-learners to make a promising vision for facilitating students' real-life inquiry (Zhang, 2019). For this reason, additional support is needed for them to pass through the reflection and envisioning along with students' progress flow more sustainably. Since teachers consider various ideas and inquiries of individuals, small groups, and whole community simultaneously, their thinking can be easily disconnected or miss crucial moments of students' progress. Thus, teachers' monitoring of students' knowledge building needs to be sustained with timely assessment and evidence of students' natural learning, which further helps teachers provide students with responsive feedback to facilitate the community's idea process. Our next study will mine students' authentic discourse as a transformative assessment to provide teachers with spontaneous feedback for their reflective envisioning of students' collective knowledge building.

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Appendix A
Code categories in Attend of teacher's reflective journals (number of frequency and percentage in parenthesis)

Code category		Code sub-category
Noticing/Reflecting on **Idea progress** (58, 33.72%)	Student/Students (55, 31.98%)	**Noticing/Reflecting on student(s)'/community's emergent/expanded/(dis)connected/shallow idea/inquiry** · Bringing/Building new information/theory/inquiry · Building emergent connection between diverse concepts by certain student(s) · Building on peer's ideas with expanded ideas/concepts · Building unclear/shallow/disconnected ideas · Expanding the community's discussion topic by certain student(s)/community · Synthesizing ideas
	Teacher's support/instruction (3, 1.74%)	**Recalling/Noticing/Reflecting on facilitating student(s)' idea progress by asking follow-up/clarifying questions** · Asking student(s) follow-up questions · Clarifying student's misunderstanding · Noticing student(s)' static idea progress
Noticing/Reflecting on **Collaboration** (8, 4.65%)	Student/Students (7, 4.07%)	**Noticing students' collaboration to advance collective ideas** · Collaborating with peers for building on/expanding/connecting ideas in groups · Finding a knowledgeable student to learn about adjacent topics
	Teacher's support/instruction (1, 0.58%)	**Recalling/Reflecting on facilitating students' collective ideas** · Facilitating student(s)' participation to build collective knowledge
Noticing/Reflecting on **student(s)' need/intent/emotion** (37, 21.51%)	Student/Students (32, 18.60%)	**Noticing on student(s)' need/intent/emotion while making progress on research** · Feeling the need of additional resource/tools or help to use them · Feeling unsure about his/her idea · Getting intent/motivation to make progress on research · Getting motivation/excitement to share his/her new enlightenment with specific group/community · Struggling while collaborating with peers · Showing byproducts to teacher
	Teacher's support/instruction (5, 2.91%)	**Reflecting on facilitating student(s)' sustained research and sharing it** · Helping student(s)' sharing of deep ideas that are missing in the community · Wondering student(s)' inquiry progress · Encouraging student(s) to keep on research out of science class
Noticing/Reflecting on use/creation of **supportive materials/tools** (28, 16.28%)	Student/Students (25, 14.54%)	**Noticing student(s)' individual/collective use/creation/sharing of supportive materials/tools** · Creating/using supportive materials/tools individually or in groups · Sharing created materials about specific topics · Using new analogy · Using tools in a community-friendly way
	Teacher's support/instruction (3, 1.74%)	**Reflecting on student(s)' purposeful use/creation of supportive materials/tools for collective knowledge** · Monitoring student(s)' purposeful use of tools · Reflecting on creation of materials to advance collective knowledge
Noticing/Reflecting on **KB practices and**	Student/Students (10, 5.81%)	**Noticing/Reflecting on student(s)' deficiency of keeping class norms and discussion about class norm**

norms (13, 7.56%)		· Highlighting/Discussing class norm to improve collective knowledge · Not reading peers' KF notes · Opening KF notes without deeper reading · Writing KF notes regardless class norms
	Teacher’s support/instruction (3, 1.75%)	**Noticing weakness in classroom practices** · Noticing weakness in classroom practices
Recalling/Reflecting on **teacher’s intent/emotion** (8, 4.65%)	Teacher’s support/instruction (8, 4.65%)	**Recalling/Reflecting on teacher’s own intent/emotion about student(s)’ idea progress/attitude** · Musing on stunning/struggling moments of student(s)’ individual/collective idea progress/attitude · Intending to highlight student(s)’ promising idea for further discussion · Matching analogy with her enlightening idea
Skip (20, 11.63%)		
Total (172, 100%)		

Appendix B

Code categories in Interpret of teacher’s reflective journals

Category		Details
Noticing/Monitoring/ Reflecting on **idea progress** (45, 26.16%)	Student/Students (9, 5.23%)	**Noticing/Reflecting on student(s)'/community’s growing knowledge with emergent connection between concepts and new inquiry** · Building emergent connection between diverse concepts/Expanding discussion topic by certain student(s)/community · Matching student(s)’ new inquiry aligned with classroom activity to deepen knowledge
	Teacher’s support/instruction (36, 20.93%)	**Monitoring/Reflecting on student(s)’ idea progress, reason behind the progress, and the need for facilitating it** · Clarifying/Noticing student’s misunderstanding · Reflecting on the need for facilitating student(s)’s individual/collective idea progress · Reviewing student(s)’ deep idea/theory · Wondering if student(s) made any progress · Wondering/Reflecting on the reason behind student(s)’ line of thinking/idea progress
Reflecting on **collaboration** (4, 2.33%)	Student/Students (2, 1.165%)	**Reflecting on student(s)’ collaboration to advance collective ideas** · Collaborating with peers for building on/expanding/connecting ideas in groups
	Teacher's support/instruction (2, 1.165%)	**Reflecting on the need for student(s)’ participation and collaboration to advance collective/adjacent ideas** · Reflecting on the need for facilitating student(s)’ participation in collective idea progress · Reflecting on the need for matching students who research adjacent concept
Monitoring/Reflecting on **student(s)’ need/intent/emotion** (26, 15.12%)	Student/Students (13, 7.56%)	**Reflecting on student(s)’ motivation and need to exchange expertise with peers** · Feeling the need of other’s help · Getting motivation to envision the next step/share his/her enlightenment with the community
	Teacher's support/instruction (13, 7.56%)	**Reflecting on student(s)’ high authority to deepen their collective knowledge while monitoring student(s)’ difficulty** · Encouraging student(s) to have high responsibility and independence to deepen individual/collective ideas · Noticing student(s)’ reluctance/difficulty · Reflecting on student(s)’ need for devoting their best knowledge to advance individual/collective with deeper theory/inquiry
Monitoring/Reflecting on **supportive materials/tools** (23, 13.37%)	Student/Students (14, 8.14%)	**Monitoring/Reflecting on student(s)’ creation of supportive materials/tools and purposeful use of them for collective knowledge building** · Creating/using supportive materials/tools individually/groups · Misunderstanding the purpose of using tools · Using new analogy
	Teacher's support/instruction (9, 5.23%)	**Reflecting on facilitating student(s)’ decent creation and use of supportive materials/tools with the help of teacher** · Facilitating student(s)’ purposeful/sustained use/creation of tools/materials · Feeling the need for teaching student(s) correct use of tools
Monitoring/Reflecting on **KB practices and norms** (12, 6.98%)	Student/Students (5, 2.91%)	**Monitoring student(s)’ recognition of class norms in building collective knowledge** · Reflecting on student(s)’ noticing of having class norms and its’ effect to class
	Teacher's support/instruction (7, 4.07%)	**Reflecting on the significance of sustaining decent class norms for collective idea progress** · Feeling the need for keeping class norms

		· Feeling the need for revising class norms
Reflection on **teacher's intent/emotion** (19, 11.05%)	Teacher's support/instruction (19, 11.05%)	**Reflecting on teacher's stunning/struggling emotion about student(s)' idea progress/attitude and her necessary instruction for collective idea progress** · Feeling the need for teacher's deep knowledge to facilitate student(s)' advanced inquiry · Matching stunning/struggling moments of student(s)' individual/collective theory building with using authoritative materials · Musing on stunning/struggling moments of student(s)' individual/collective idea progress/attitude
Skip (43, 25%)		
Total (172, 100%)		

Appendix C

Code categories in Make Move of teacher's reflective journals

Category		Details
Reflecting on/Envisioning **idea progress** (38, 22.09%)	Teacher's support/instruction (38, 22.09%)	**Reflecting on/Facilitating student(s)' best and growing ideas to the community through advanced strategy and collaboration with co-teacher** (38, 22.09%) · Building on student(s)' KF note to share teacher's idea and deepen student(s)' idea/inquiry · Envisioning an alternative strategy to deepen student(s)' idea/theory/inquiry or clarify student(s)' misunderstanding · Facilitating student(s)' devotion to their best knowledge to advance individual/collective with deeper theory/inquiry · Having a talk with student(s) to deepen student(s)' idea/inquiry · Highlighting student(s)' emergent/deep idea/theory with the community · Referencing co-teacher's idea to facilitate student(s)' collective knowledge building
Envisioning **collaboration** (6, 3.49%)	Teacher's support/instruction (6, 3.49%)	**Facilitating student(s)' partnership to leverage and advance collective knowledge** (6, 3.49%) · Envisioning student(s)' collaboration to deepen/connect emergent idea · Matching student(s) with knowledgeable student(s) researching on adjacent topics
Recalling/Reflecting on/Envisioning **student(s)' need/intent/emotion** (31, 18.02%)	Student/Students (4, 2.32%)	**Recalling/Reflecting on student(s)' expression of their growing enlightenment/excitement/motivation** (4, 2.32%) · Sharing student(s)' enlightenment with the community for peer(s)' understanding of its' value · Speaking out student(s)' increasing excitement/motivation to enjoy researching
	Teacher's support/instruction (27, 15.70%)	**Sustaining/Facilitating student(s)' positive intent/need to advance collective knowledge while providing student(s) in need with adequate help** (27, 15.70%) · Envisioning an alternative way of satisfying student(s)' intent/need · Envisioning an alternative way of overcoming student(s)' reluctance/difficulty · Having a talk with student(s) to check/sustain his/her intent/need · Highlighting student(s)' intent/need
Recalling/Reflecting on/Envisioning **supportive materials/tools** (29, 16.86%)	Teacher's support/instruction (29, 16.86%)	**Facilitating the best adoption of supportive materials/tools to advance collective knowledge** (29, 16.86%) · Linking student(s)'/community's emergent idea/concept to KF/ITM · Recalling/Reflecting on/Facilitating student(s)' purposeful/effective/correct use of tools/materials
Reflecting on/Envisioning **KB practices and class norms** (12, 6.98%)	Teacher's support/instruction (12, 6.98%)	**Improving class norms and facilitating student(s)' cultivation of the norms to advance collective knowledge** (12, 6.98%) · Highlighting/Facilitating class norms for student(s) to cultivate the norms · Improving/Revising class norms
Envisioning **tracking student(s)' ideas** (13, 7.56%)	Teacher's support/instruction (13, 7.56%)	**Envisioning/Sharing better ways of timely monitoring of the community's idea progress** (13, 7.56%) · Enhancing/Highlighting student(s)' and teacher's tracking of ideas more effectively · Tracking student(s)' emergent/growing ideas
Skip (43, 25%)		
Total (172, 100%)		

Exploring the Prospects of Knowledge Building in Advancing Computational Thinking

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Abstract: This paper explores prospects of Knowledge Building in advancing computational thinking by drawing upon commonalities between these fields and opening new possibilities for enhancing discourse surrounding ideas and artifacts and for assessing levels of computational thinking. Toward this end I review definitions of computational thinking, particularly in the context of K-12 education. Factors of significance for integration into Knowledge Building include discourse to generate, extend, and explore ideas and artifacts from a computation perspective and use of new forms of assessment so that computational thinking is integral to day-to-day knowledge work. To determine the first level of computational thinking three Knowledge Forum databases of an elementary school were analyzed for the use of computational thinking vocabulary prior to any committed time to advance computational thinking. As expected, results showed very little use of computational keywords. Next design iterations will facilitate discourse surrounding computational ideas and artefacts to facilitate an advanced level of computational thinking involving computational tools as mediums of expression, connecting, and questioning. In addition, as part of a global *Saving the Planet, Saving lives* initiative, students' work will be connected to a broader network of communities while working on parallel issues to support sustained creative work with ideas.

Introduction

Worldwide attention to computational thinking can arguably be traced to Jeanette Wing's (2006) influential article where she claims that computational thinking is a "universally applicable attitude and skill set" (p.33) that should be added to every child's analytical ability. Debates that followed in the academic community focused on its definition and means, with a lack of consensus on how it should be taught and evaluated (Barr & Stephenson, 2011; Brennan & Resnick, 2012; Denning, 2017; Grover & Pea, 2013a). In this paper, I outline literature that defines computational thinking and the different attempts made to bring computational thinking to K-12 education. I discuss approaches to assess computational thinking in the context of visual programming. Finally, I highlight the prospects of Knowledge Building as a pedagogical approach to advance computational thinking.

Background

The roots of computational thinking can be traced to the work of computing pioneers like Alan Perlis who claimed that computing would eventually automate all processes and 'algorithmic thinking' will pervade all fields (Denning, 2017; Guzdial, 2008). Seymour Papert (1980) extended this vision in his book Mindstorms in which he recognized the benefits of teaching students how to program and argued that working with computers can influence how people think. Papert emphasized the role of computer modeling in learning and argued that procedural thinking can help children form concrete forms to areas of knowledge previously considered too abstract.

A resurgence of interest in computational thinking followed the publication of Wing's seminal article "Computational Thinking", where she describes computational thinking as an approach to solve problems, design systems, and understand human behaviour by drawing on key concepts in computer science (Wing, 2006). In a more refined definition, Wing accepts that computational thinking is "*the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out*" (Cuny et al., 2010, p.1). Alfred Aho (2012) echoes Wing's emphasis on considering computational thinking a thought process but emphasizes it should be used in conjunction with a clearly defined model that fits with the problem being investigated. Aho defines computational thinking as *"the thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms"*(p.832). When a model is not available, computational thinking becomes a research activity that involves devising new models to formulate and solve problems.

Computational Thinking in K-12: Definitions and Frameworks

The renewed emphasis on computational thinking catalyzed by Wing's article prompted a number of organizations and researchers to propose an operational definition for computational thinking in K-12 (Barr & Stephenson, 2011; Denning, 2017; Grover & Pea, 2013a; Wing, 2008). In 2010, the National Research Council conducted two workshops to explore the nature and scope of computational thinking and its educational implications based on Wing's definition (NRC, 2010; NRC, 2011). In the first workshop, participants agreed that abstraction is the keystone of computational thinking but there was no consensus on how computational thinking should be defined. Discussions in the second workshop that focused on pedagogy also showed lack of agreement on the best approaches to teach computational thinking (Grover & Pea, 2013a).

Another project co-led by the International Society for Technology in Education (ISTE) and the Computer Science Teacher Association (CSTA) aimed to provide a framework to help educators bring computational thinking to different subjects in K-12. The efforts resulted in an operational definition of computational thinking that describes it as a problem-solving process that involves problem formulation, analysis and organization, use of models and simulation, algorithmic thinking, automation, thinking of and testing alternative solutions, and generalizing the problem-solving process to be used across domains. They determined that the ability to persist in solving problems, to tolerate complex, ambiguous, and open-ended problems, and to collaborate with others towards a shared goal are essential attitudes that enhance computational thinking skills (Barr et al., 2011). Based on these outcomes, Barr and Stephenson (2011) produced a structured checklist that identified core computational thinking concepts and suggested examples of how they might be embedded in different subjects. Another notable effort made by the Royal Society (2012) in the UK produced a more precise definition for computational thinking as the *"process of recognising aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes*" (p.29).

Selby and Woollard (2013) highlight the necessity of a robust definition of computational thinking to facilitate proper curriculum design and assessment. Their effort to collate common concepts that appeared in literature determined that computational thinking is a thought process that reflects the ability to systematically apply abstraction, decomposition algorithmic thinking, evaluation, and generalization to provide automated solutions. Weintrop et al. (2016) argue that embedding computational thinking in math and science disciplines will give learners a more realistic understanding of the fields and provide them with a deeper content learning experience. They define computational thinking in terms a taxonomy composed of four main categories of practices, including data, modeling and simulation, computational problem solving, and systems thinking. Kotsopoulos et al. (2017) propose a more pedagogically oriented framework for introducing computational thinking that consists of unplugged, tinkering, making/constructing, and remixing activities.

Computational Thinking, Creativity, and Knowledge Construction

Most definitions of computational thinking seem to focus on skills and attitudes required to solve complex problems where the use of technology is key (e.g. Barr & Stephenson, 2011; Grover & Pea, 2013a; Weintrop et al., 2016). A broader perspective suggests that computational thinking can foster creativity by allowing students to build tools that can have a major impact on society. Mishra and Yadav (2013) claim that computational thinking facilitates new forms of expression and argue that combining computational thinking with deep knowledge of a discipline can result in creative solutions otherwise not possible. Romero et al. (2017) argue that creative programming activities that present learners with ill-defined problems can be used to foster knowledge building through orchestrating and enhancing creative activities. More recently, Paniagua and Istance (2018) classify computational thinking as an innovative pedagogy which can facilitate the development of transversal skills and promote creativity and meaningful learning. While they acknowledge the importance of coding and algorithmic thinking, they argue that engaging students in knowledge creation is key to the process;

> "*computational thinking is sometimes seen as 'algorithmic thinking' and writing codes, but if the goal is to learn how to look to at a problem in new ways, or to find new answers according to a given sets of possibilities - as a computer or programming language might -, then the skills associated with the generation of ideas and openness to develop and explore ideas need to be practised along with computational thinking skills."* (p.107)

This view is corroborated by ISTE standards which state that students should be computational thinkers and knowledge constructors if they are to succeed in a constantly evolving technological world. As knowledge constructors, students should build knowledge by "*actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions*." (ISTE, 2016, p.1).

Computational Thinking through Programming

Over half a century ago Perlis anticipated what is happening today: machine automation is changing operations across all disciplines (Gudzial, 2008). Perlis's call to teach programming to everyone was elaborated by Papert (1980) whose work on developing the Logo programming language was accompanied by a vision that it is the child who should program the computer and not vice versa. In doing so, the child "*both acquires a sense of mastery* *over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building"* (p.5).

While the attempts outlined earlier consider computational thinking a *thought* or *problem-solving* process, Brennan and Resnick (2012) propose a framework that adopts a constructionist approach to learning (Harel & Papert, 1991) which highlights that learning takes place by engaging learners in the design and development of artifacts. The framework is based on Resnick's work on Scratch, a visual programming environment that enables children to learn programming by creating, sharing, and collaborating on interactive and meaningful projects (Maloney et al., 2010). The framework is used to determine how programming activities on Scratch can support the development of computational thinking in young learners in terms of three dimensions. First, *computational concept*s that learners engage in while programming, such as loops, conditions, and operators. Second, *computational practices* that learners develop as they work with different concepts, which include being incremental and iterative, testing and debugging, reusing and remixing, and abstracting and modularizing. Third, *computational perspectives* that learners develop about themselves and about their worlds, which includes their ability to express ideas, connect with others in their community, and question their experiences in the technological world and respond to these questions via design (Brennan & Resnick, 2012).

Potentials and Challenges

Despite calls for alternative views to introduce computational thinking in K-12, current research shows that teaching visual programming results in substantial gains in students' capacity to think computationally (Lye & Koh, 2014; Zhang & Nouri, 2019). This may be due to the proximity of visual programming representations to human language which reduces the cognitive load on novice programmers and allows them to focus the structures and logic of their program (Kelleher & Pausch, 2005; Maloney et al., 2010). Tools like Scratch can help students think computationally where the ultimate goal is not simply to code but to produce artefacts that genuinely interests them (Maloney et al., 2010). For example, a study conducted by Lee (2010) found that Scratch enabled primary school students to learn programming while creating multi-media language-arts projects. Another study conducted by Burke (2012) on middle school children learning languages via Scratch suggests that digital storytelling can effectively facilitate learning composition and at the same time introduce students to coding at early ages.

While it is unreasonable to expect all students to become programming experts, some researchers argue that basic programming is an important 21st century competency (Barr & Stephenson, 2011; Grover & Pea, 2013a; Weintrop et al., 2016). Others such as Shein (2014) assert that not all students need coding skills although learning how to think like a programmer can be helpful in many areas. Shein argues that teaching programming views coding as the goal which puts '*the method before the problem*'. Grover and Pea (2018) share this concern and argue that problem formulation is key in the problem-solving process, which can be taught without programming or computers. Other views question whether computational thinking, through programming or otherwise, is indeed as important as promoted by advocates. Hemmendinger (2010) believes the benefits of computational thinking outlined by Wing are overstated and "scarcely peculiar to computing" (p.4). He suggests focusing less on computational *thinking* and more on computational *doing* - figuring out how to use computational tools to accomplish work in new ways. Denning (2017) agrees that recent definitions of computational thinking made overreaching and unsubstantiated claims and expectations, leaving teachers confused on how they should teach or assess computational thinking. Easterbrook (2014) criticizes the overly simplistic notion of computational thinking as a technology-driven problem-solving approach, and proposes systems thinking as a more sustainable approach that considers the interrelationships between technology, human behavior, and environmental impacts.

Assessment

Measuring students' computational abilities remains a primary challenge that teachers and educational researchers still struggle with. Denning (2017) suggests directly testing for competencies rather than knowledge, but provides no direction or examples of how to effectively assess the development of computational thinking skills. While there have been some attempts to develop tools for assessing computational thinking (for e.g. Chen et al., 2017; Zhong et al., 2016), it seems that each tool will only provide a partial view to students' computational thinking (Román-González et al., 2019). Brennan and Resnick (2012) propose three approaches for assessing their framework: Scratch project portfolio analysis, artifact-based interviews, and discussions around design scenarios. However, they acknowledge the limitations of these approaches and call for multiple and alternative means of assessment, highlighting the importance of reflection and discourse about the produced artefacts. A review of empirical research conducted by Lye and Koh (2014) on teaching and learning computational thinking through programming showed dearth of research, with only 9 peer-reviewed studies conducted in K-12, mostly in after-school settings. Moreover, most studies reviewed explored the *computational concepts* dimension of the framework, although the other two dimensions - *computational practices and perspectives* – have become more relevant as the basis for introducing computational thinking in K-12, as they pertain to the common idea of computational thinking as a transferable, problem-solving thought process (Aho, 2012; Barr et al., 2011; Cuny et al., 2010). To examine computational practices and perspectives, Lye and Koh (2014) suggest capturing students' programming processes by recording on-screen activities and engaging students in think-aloud protocols. A more recent review by Zhang and Nouri (2019) still revealed that most studies examined computational thinking *concepts* with fewer studies exploring *practices* and *perspectives,* and reemphasized Lye and Koh's (2014) call for more scholarly research that explores these two dimensions. In this spirit, I address Knowledge Building as carrying potential for advancing computational thinking.

Knowledge Building to Promote Computational Thinking

Knowledge Building is a principle-based, educational approach developed by Scardamalia and Bereiter, both pioneers of computer-supported collaborative learning (CSCL). The Knowledge Building approach focuses on the growing need for the ability to work creatively with knowledge. The essence of Knowledge Building is the "*production and continual improvement of ideas of value to a community*" through shared discourse that aims to advance the knowledge and expertise of the community (Scardamalia & Bereiter, 2003, p.1371). The concept Knowledge Building as the collaborative creation and advancement of public knowledge can be considered in the light of six themes: 1) community rather than individual knowledge advancement, 2) idea improvement rather than correct/incorrect ideas, 3) knowledge *of* (deep knowledge) rather than knowledge *about*, 4) discourse as collaborative problem solving rather than argumentation, 5) constructive use of authoritative resources, and 6) understanding as emergent (Scardamalia & Bereiter, 2006). Knowledge Building discourse is facilitated by the Knowledge Forum technology that is especially designed to support and promote advanced knowledge work (Scardamalia, 2004).

Teacher reports suggest that students engaged in Knowledge Building surpass expectations with respect to creativity, teamwork, problem solving, and other indicators known as 21st century competencies (Khanlari et al., 2019). Research indicates that students engaged in Knowledge Building experienced gains in core discipline knowledge (for e.g., Chan & van Aalst, 2003; Zhang et al., 2011) which Mishra and Yadav (2013) deemed as necessary if computational thinking is to result in the production of creative technology-enhanced solutions. Moreover, evidence indicates that Knowledge Building advances a range of literacies and skills such as collaboration, argumentation, digital literacies, and problem-solving skills (for e.g. Gan et al., 2010; Zhang et al., 2007), which were highlighted in the literature as core computational thinking competencies. The use of computational vocabulary is also noted in computational thinking literature as a core capability that creates awareness of computational practices and promotes a classroom culture conducive to computational thinking (e.g. Barr & Stephenson, 2011; Lu & Fletcher, 2009), but so far there is a dearth of research investigating practices to promote the use of computational thinking vocabulary. Knowledge Building research shows that discourse were students discuss and build-on each other's ideas and experiments results in significant growth of students' productive academic, domain-specific, and cross-domain vocabulary (Hong et al., 2015; Khanlari et al., 2019; Sun et al., 2008).

Lye and Koh (2014) argue that proper guidance on the cognitive aspects of the computational *practices* and *perspectives* is necessary for a proper educational experience. They suggest that educational environments that foster computational thinking should be designed to promote authentic problem solving. That is, students should work on problems relevant to them, which is emphasized in the Knowledge Building principle *Real Ideas, Authentic Problems*. Environments should also allow teachers to scaffold the process of problem-solving that enables learners to make their thinking process more explicit, particularly while working on programming projects (Lye & Koh, 2014). An important feature in Knowledge Forum is the *Scaffold*, which can represent different epistemological terms such as *I need to understand* or *putting our thoughts together* that can help frame student's thinking and allow them to express and reflect on their ideas. Scaffolds can be customized to support the particular discourse needs and can be searched and analyzed to determine patterns of use and contribution to the advancement of student and community knowledge (Scardamalia, 2004).

Grover and Pea (2013a) argue that there is a scarcity of studies that consider contemporary research in the learning sciences in areas like socio-cultural learning, and activity, interaction, and discourse analyses. Realizing this gap, the authors conducted a one-day workshop that introduced middle-school students to programming concepts via a discourse-intensive pedagogy. The curriculum was designed around engaging students in "*knowledge building discussions in concert with engaging in computationally rich activities*" (Grover & Pea, 2013b, p.724). Results show that instructor and participants' responses to emergent issues triggered opportunities for introducing more advanced computational concepts and resulted in a significant growth in computational vocabulary. Despite being an exploratory study, the findings support the idea that Knowledge Building discourse around programming projects can result in significant advancements of computational thinking vocabulary and competencies. Moreover, examining students' Knowledge Building discourse and augmenting the findings with results of analytical tools that evaluate programming projects (such as Dr. Scratch) can offer multiple means of assessing computational learning and help provide a more holistic view of student computational understanding (Brennan & Resnick, 2012; Grover, Cooper, & Pea, 2014).

Knowledge Building, Programming, and Papert's Vision

Papert warned against taking a technocentric perspective to programming; the centrality should not be on the technical object, but rather on the culture. According to Papert (1987), technocentric approaches "*often betray a tendency to think of 'computers' and of 'Logo' as agents that act directly on thinking and learning; they betray a tendency to reduce what are really the most important components of educational situations—people and cultures—to a secondary, facilitating role*." (p 23). This technocentric view is perhaps what stood in the way of Papert's vision of a world where children do not just interact with technology but are able to create their own models and express their ideas using technology. As highlighted by Resnick (2012), most teachers today see programming as a "narrow, technical activity, appropriate for only a small segment of the population" (p.42). Hence, reviving Papert's vision requires multi-faceted efforts to bring about technologies that are more social and meaningful with the potential to fundamentally change educational practice. Visual programming tools such as Scratch are considerable leaps towards this direction by providing platforms where learners can create personally meaningful and shareable projects (Resnick, 2012). However, while such tools simplify the acquisition of cognitive skills, primary focus is not on empowering student discourse about their ideas. Students should be able to use code for creative self-expression and to solve problems that matter to them in an environment that promotes student agency where new knowledge emerges out of social interactions. Hence, a combined, interdisciplinary approach to teaching computational thinking where the primacy is to improvable ideas and facilitating students' epistemic agency can help realize this vision. In this setup, students can engage in Knowledge Building discourse where multiple perspectives and critiques are encouraged, not only about technical aspects of digital artefacts but also with how these artefacts connect with other areas of their lives. Knowledge Building discourse can be facilitated using Knowledge Forum technology, where scaffolds can be customized and used "opportunistically and flexibly" (Scardamalia, 2004, p.189) to guide student inquiry and thinking in multiple directions while working on designing and creating programming projects.

Use of Computational Thinking Vocabulary in Knowledge Building Environments

Tsoukas (2009) explains that dialogue "aims at removing some kind of unsettledness (or perplexity) experienced by the parties involved, through their reasoning together by verbal exchanges." (p.943). Specifically, productive dialogue takes place when participants find a *common langua*ge. Hence, for students to engage in productive computational thinking discourse and be able to communicate their computational ideas more effectively a common computational thinking vocabulary should be established. As argued by Lu and Fletcher (2009), a Computational Thinking Language consisting of vocabularies that capture core computational thinking concepts like abstraction and information should permeate pedagogy.

As a starting point to research that explores the prospects of Knowledge Building in advancing computational thinking, I searched three Knowledge Forum databases of an elementary school for occurrences of certain computational thinking keywords and their common derivatives as students engaged in Knowledge Building discourse in different science topics (see Table 1). Results show that in all three databases students barely used any keywords (see Table 2, Table 3, and Table 4).

Table 1 Computational thinking keywords

Algorithm	Conditional	Input	Output	Initialize	Variable
Boolean	Sequencing	Branching	Iteration	Loop	Abstraction
Debug	Debugging	Binary	Data	Automation	Decomposition
Function	Parameter	Analysis	Simulation	Parallelization	Program
Testing	Pattern	Coding			

Table 2 Computational thinking keywords (2017-2018 database)

Keyword	Number of occurrences
Data	2
Programs	1

Patterns	1

Table 3 Computational thinking keywords (2018-2019 database)

Keyword	Number of occurrences
decompose	2
Testing	1

Table 4 Computational thinking keywords (2019-2020 database)

Keyword	Number of occurrences
Data	16
decompose	1
Program	1
Testing	1

A closer look at the notes where the keywords occurred revealed that they were not used within a computational thinking context, except for one note in the 2017/2018 database where the student used both 'patterns' and 'data' in the same note: "… *If we can figure out some of the trends and patterns of the past maybe we can use that information and data to do predict the climate in the future*". This is not entirely surprising as the school does not teach computational thinking or integrate computational thinking concepts into the curriculum of other subjects.

Evidence from Grover and Pea's pilot study (2013b) of introducing computational thinking using discourse-intensive pedagogy suggests that learning environments may be "consciously designed for computational discourse to help children develop a vocabulary that is faithful to CS as a discipline" (p.727). My own viewpoint for advancing computational thinking is based on designing two main interventions. The first is to introduce students to computational thinking concepts via computational *Knowledge Building* discourse. In their computational thinking class students will propose new projects and discuss implementation interspersed with work on Scratch. The belief and goal are that engaging students in face-to-face Knowledge Building talk as well as Knowledge Forum discourse will support them while working on programming projects and will help them acquire transferable computational thinking competencies and develop a computational thinking vocabulary. To facilitate computational thinking discourse, Knowledge Forum scaffolds can be created and adjusted for different grade levels to inspire student generation of programmable ideas (for e.g. this program could be improved by…, a new pattern..., a better sequence…). The second stage involves leveraging the acquired computational thinking competencies to engage students in the co-creation of digital artefacts (for e.g. simulations, digital stories) that address real problems tackled while engaging in science Knowledge Building discourse. Scaffolds can be created to facilitate the idea of 'doing science' through programming (for e.g. such "we need a simulation to show…, this model would clarify). The expectation is more sustained, productive, and integrative use of computational thinking vocabulary, concepts, and practices over time, and the development of students' perspective for programming as a tool to create artefacts that are useful and valuable to their communities.

Future Research

This initial, benchmark-establishing research involved analysis of three Knowledge Forum databases of an elementary school for the use of computational thinking vocabulary over a 3-year time period. The goal was to take a snapshot, prior to any direct engagement in computational thinking, to determine use in unsupported contexts. Next stages will involve design iterations, using scaffolds and visualization of computational concepts to engage students more productively in discourse surrounding computational ideas and artifacts, with Brennan and Resnick's dimensions as the guiding framework. Students will use Knowledge Forum for planning, discussion, and evaluation of the games, animations, simulations and models they create using Scratch. In addition, as part of a global *Saving the Planet, Saving lives* initiative, students' work will be connected to a broader network of communities while working on parallel issues to support sustained creative work with ideas. A "levels of computational thinking" analysis will be developed, extending from limited use of terms and use without computational implications evident to seeing and using computational tools as mediums of expression, connecting, and questioning.

Conclusion

The aim of this paper is to shed light on different attempts to define and facilitate computational thinking in K-12 to demonstrate the prospects of Knowledge Building as a promising approach to advance computational thinking. Engaging students in Knowledge Building discourse, with the use of appropriate scaffolds to guide, promote, and capture students' ideas and thought processes while working on programming projects is likely to contribute positively to advancing computational thinking. Factors of significance for integration into Knowledge Building include discourse to generate, extend, and explore ideas and artefacts from a computational perspective and use of new forms of assessment so that computational thinking is integral to day to day knowledge work. Research in this area will be a valuable contribution to the field of computational thinking education as well as the Knowledge Building literature.

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Supporting Knowledge Building with Analytics and Augmented Intelligence – Building on the Emerging Works

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Abstract: Knowledge building pedagogy requires teachers to be adaptive and apply appropriate principles in guiding students' emergent idea improvement. While there are emerging works on the use of analytics to support knowledge building, this area of work is still under-developed. This paper presents a review of the current state of work on the use of learning analytics with knowledge building data and multimodal data and identifies areas where artificial intelligence (AI) could be harnessed to provide adaptive support. A set of guiding questions that can be used to guide research and development in this area is also proposed.

Introduction

Knowledge Building research (Scardamalia & Bereiter, 2015), is one of the most enduring and prominent research themes in the learning sciences (Chen & Hong, 2016). It remains relevant as it aims to tackle one of the most intractable problems in this Knowledge Age: developing knowledge building capacity of people. One distinct characteristic of this line of research is that the advancement in the supportive technologies, Knowledge Forum®, as well as related technologies such as promising ideas tool, were developed in tandem with the progress made in theories. Knowledge building research has taken a design implementation approach, which constantly tests and refines the design principles to tackle authentic classroom challenges. This paper discusses how to leverage advances in analytics and artificial intelligence (AI) to augment knowledge building processes.

Designing and facilitating knowledge building can be challenging as it differs from the predominant instructional practices that have prescriptive procedures to follow. To design for knowledge building lessons, a teacher needs to adopt a principle-based approach (Zhang et al., 2011), and follow students' collective idea development closely. Besides, it also advocates an embedded assessment that requires one to examine students' knowledge artifacts as evidence of their knowledge advancement, rather than using the predominant testing-after-learning assessment regime. All these calls for adaptive classroom practices (Männikkö & Husu, 2019) that require constant decision making as the students engage in collaborative idea improvement. To address these challenges, teachers and students need relevant information for their decision making. In terms of technological support, current computer-supported collaborative learning technologies focus on "static forms of support, such as structured interfaces, prompts, and assignment of students to scripted roles" (Rosé & Ferschke, 2016, p. 663), no doubt there is emerging research that aims to develop analytical tools or the external processing of learning analytics to work on the KF data. Building on the advancement in technologies and data science, this paper proposes how the power of AI could be harnessed to provide learning support. The intention is not to use AI to replace human intelligence in guiding knowledge building work; doing so will be running against the very purpose of developing students' capacity in knowledge work. Rather, the focus is on how students and teachers could work in intellectual partnership with computers that generate timely insights from data, to engage in knowledge building more efficiently and effectively. Thus the choice of the term augmented intelligence, and not AI, in the title of this paper.

For clarity, we start with a short explanation of analytics and AI for education. Analytics, in essence, refers to the systematic applications of quantitative methods (including statistics) to enhance decision making (Davenport & Harris, 2017), especially in situations when there are a massive amount of data to make sense of. Analytics can be *descriptive*, which is based on data from past events, or *predictive*, which projects into future possibilities (Reavie, 2018). While some experts (e.g., Reavie, 2018) opined that AI can make assumptions and learn autonomously but analytics does not, others view AI as a continuum from analytics. For example, Davenport (2018) labelled AI as Analytics 4.0.

AI refers to studies and applications of how machines perceive and process information from the environment and take actions towards achieving a goal, thus simulating the abilities of cognitive thinking and exhibiting adaptive behaviors, just like human beings (Hinojo-Lucena et al., 2019). Developed since the 1950s, the resurgence of interest in AI in the 21st century can be attributed to the advancement in computing power and ability to process big data, which enables translation into many practical applications, such as image recognition and auto-text correction. AI often involves machine learning, which primarily focuses on the study of computer algorithms that can automatically improve through experience (Mitchell, 1997). Deep Learning is a machine learning technique that seeks to define neural networks based on pattern recognition from input data (Contreras & De La Rosa, 2016). The "deep" in Deep Learning refers to the multiple transformation layers and levels of representation that lie between the neural network inputs and outputs (Hernández-Blanco et al.,2019).

There are some emergent works on the use of analytics for knowledge building, but it is still an under-researched area.

A review of analytics/AI for knowledge building framework

A search was conducted via the authors' library system that integrates over 50 databases. The search terms "knowledge building" or "knowledge creation" AND "analytics or big data or artificial intelligence" AND "education or school or learning or teaching or classroom or education system" were entered. There were 90 articles identified and 18 articles were shortlisted after going through the abstracts. After reading the articles, only 9 were found to be relevant to knowledge building (Scardamalia & Bereiter, 2015). This small number is not surprising given that research on the use of analytics and AI for knowledge building is in its infancy stage. For parsimony, we only included one article on the same product or approach. To analyze the current work, the following questions were asked: (1) which aspect(s) of knowledge building is/are supported?; (2) what are the related knowledge building principles? (3) what kinds of analytics or AI techniques are used?; (4) What are the main outcomes of the studies? Table 1 summarizes the relevant information among the studies presented in these 9 papers that involved analytics or the use of machine learning.

Among these 9 articles, most of the studies focus on socio-cognitive aspects of knowledge building and the associated principles related to knowledge building discourse and idea improvement. Also, visualization of analytics tools was used by students in three studies (Chen & Zhang, 2016; Hong et al., 2015; Resendes et al., 2015), often as students' choice rather than teacher's instruction or scripted activities. For the other studies, analytics or machine learning are used by researchers as research tools. There is only one study (Zhu et al., 2019) that investigated students' emotions associated with knowledge building. Concerning the types of analytics or AI technologies employed, a combination of a range of technologies was used: KF analytics tools (Hong et al., 2015; Resendes et al., 2015), text mining and topic modelling (Chen et al., 2015; Chen, Zhang, & Lee, 2013; Lee & Tan, 2017), temporal analysis (Chen et al., 2017; Lee & Tan, 2017), latent semantic analysis and frequent sequence mining (Chen et al., 2017), KBDex analytics followed by betweenness-centrality trends and degree-centrality/betweenness-centrality graph with clustering (Lee & Tan, 2017), speech emotion analysis, prosody, sentiment analysis, content analysis of multimodal data (Zhu, Xing, Costa, Scardamalia, & Pei, 2019), and sequential patterns analysis (Zhu et al, 2019).

How do we make sense of these emerging works and more critically, how and where do we go from here? One apparent and expected similarity among these studies is the central role of the guiding principles of knowledge building. Another observation is that the study on the emotional aspect of knowledge building is only featured in one study, although we can argue that such a study, in general, is also lacking in knowledge building research. Nevertheless, the advancement in technologies and analytics present opportunities to explore the emotional aspects of knowledge building. For example, natural language processing and sentiment analysis could be employed to study texts written by students. Advancement in the internet of things such as wearable devices could also be explored to provide a constant stream of physiological data (e.g., heartbeat), which afford moment-to-moment analyses of emotions that are not feasible in the traditional methods of self-report and use of psychological instruments. One less apparent observation is that the analytics could be designed for the students ultimately, but in many studies, used by the researchers.

Table 1. Research on the use of analytics and AI to support knowledge building

Authors	Cognitive-social-emotional	Related KB principles	Analytics/AI	Outcomes
Oshima, Oshima, & Matsuzawa (2012)	Socio-cognitive	KB discourse	Text mining KBDeX: social network analysis (of notes and ideas in the notes)	KBDeX analysis provides an alternative assessment for discourse advancement in knowledge building.
Chen, Resendes, Scardamalia, & Chuy (2012)	Socio-cognitive • Promising ideas	KB discourse Real ideas; idea improvement; diversity of ideas; Rise above	Topic modelling: • Latent semantic analysis – compare students' ideas with authoritative sources	Students can make promisingness judgement; scientific level and domain knowledge improved.
Hong, Scardamalia, Messina, &Teo (2015).	Socio-cognitive • Vocabulary growth; • vocabulary overlap with curriculum • Social network	All; principle-based design	• Use of analytics as knowledge building tools • Vocabulary • Analyzer, a Social Network Tool, and a Semantic Overlap Tool.	Increase in use of key terms; shift from problem generation to self-assessment; analytics tools help students to be more self-directed
Resendes, Scardamalia, Bereiter, & Chen (2015)	Meta-cognitive-social	KB discourse	• Word clouds • Epistemic Discourse Moves tool • KBDeX: degree centrality (DC), betweenness centrality (BC) and closeness centrality (CC).	Grade 2 children can engage in metadiscursive reflection and their vocabulary development. Feedback tools useful for children to address group cognition.
Chen & Zhang (2016)	Socio-cognitive Promising ideas	• Epistemic agency • KB discourse • Idea centric principles	• Text analysis to merge promising ideas and calculate similarities among promising ideas • Epistemic Discourse Moves tool • Temporal analytics • Automatic text analysis and topic modelling	Framework for KB analytics. Characteristics of KB analytics: agency-driven, choice-based, and progress oriented.
Lee & Tan (2017)	Cognitive Promising ideas	Idea improvement; diversity of ideas	• Text mining • Temporal analytics • Cluster analysis • KBDeX: degree centrality (DC), betweenness centrality (BC) graph over time, DC-BC graph	Temporal analytics and machine learning can help to identify promising ideas
Chen, Zhang, & Lee (2013)	Socio-cognitive Meta knowledge building structure	KB meta-discourse, idea improvement and rise above	• Multilevel analysis and visualization of threads of ideas	Visualization of Idea-threads helps students to engage in meta-discourse and rise above of ideas.
Chen, Resendes, Chai, & Hong (2017)	Socio-cognitive Discourse move	KB discourse	• Temporal analytics • Lag-sequential Analysis (LsA) • Frequent Sequence Mining (FSM)	Identification of patterns and sequence of discourse moves among more productive KB threads
Zhu, Xing, Costa, Scardamalia, & Pei (2019)	Cognitive-Emotions	Emotions and idea improvement	• Speech emotion analysis (prosodic analysis) • Sentiment analysis from text	Identification of types of emotions that co-occur with different level of idea improvement

Guiding questions for augmenting knowledge building with analytics or AI

To guide future development of intelligent collaborative learning supports, Rummel, Walker and Aleven (2016) proposed that researchers could consider educational theory and multiple factors – the timing of support, psychological realms of support (cognitive, social, metacognitive, affective), mode of support (implicit or explicit), locus of support (direct or indirect), and target of support (group formation, peer support, domain support or social skills). Building on Rummel et al. (2016) recommendations and considering agenda of knowledge building research, we propose two sets of guiding questions, starting with the focus of knowledge building, then the nature and types of analytics or AI to augment knowledge building. Moving forward, developing a set of guiding questions for the use of analytics or AI to augment knowledge building could be useful. One approach is to envision what kinds of questions the researchers of the above-reviewed studies might ask. It is important to take this set of questions in totality for holistic considerations.

1a. What challenges are we addressing? Which principles of knowledge building is/are the focus?

As in most design-implementation research, challenges encountered in the design and/or implementation often provides the impetus for change innovation. The challenges can be multi-dimensional: ranging from technical developmental challenge, methodological challenge, and practical challenges. Given that design of knowledge building takes a principle-based approach (Zhang et al., 2011), identify the specific principle(s) is a critical consideration, which is apparent in the studies reviewed. For instance, the issue of identifying promising ideas motivated several studies (Che et al., 2012; Chen & Zhang, 2016; Lee & Tan, 2017) and is related to the idea-centric principles of knowledge building.

1b. Which aspects of knowledge building is augmented (e.g., Social, cognitive, metacognitive, emotional)?

Identifying the aspects of knowledge building or what Rummel et al. (2016) refer to as the psychological realms (cognitive, social, metacognitive and affective) could be useful as it has implications on the source of data (see Question 2 below) as well as the outcomes. For example, students' notes (text) could be a logical source for the cognitive and metacognitive aspects of knowledge building, and their interaction patterns the source of social aspects of knowledge building. That said, socio-cognitive interactions are also analyzed as in the case of KBDex (Oshima et al., 2012). This question to determine specific aspects of KB as we work with the huge potential of AI is especially important to avoid two extremes: to avoid narrowing the measure of these critical learning processes into a "score", and to avoid getting into a web of data that does not make much sense to the practitioner.

1c. How does this augmentation enable the advancement of knowledge building beyond the current methods (e.g., supporting idea advancement)?

This question is critical because we need to be cognizant that some of the goals and practices of analytics or AI in the field may not be compatible with the guiding principles of knowledge building. For example, the use of conversational agents that emulate good tutor's dialogue (e.g., Evens & Michael, 2006) may not be appropriate for knowledge building because it might position the "e-tutor" as the mediator of the conversation among students, and discourage peer-to-peer interaction – a situation we want to avoid in knowledge building. On the other hand, research on using machine learning to perform auto-segmenting of discourse (Mu et al., 2012) and automatic text tagging (Rosé et al., 2008) could be applied to knowledge building discourse move and extend the study by Chuy et al. (2011). If a machine can automatically perform segmenting of discourse and detect discourse moves, then automatic adaptive support can be developed to facilitate or encourage productive students' interactions (Walker, Rummel, & Koedinger, 2011); for instance, reflective prompts could appear to ask students to reflect on their discourse move or student-activated resources or hints about their progress of knowledge building could be provided.

2a. Which types of data are involved? (e.g., text, social interactions, cognitive interactions, voice, video, multimodal)? How do we integrate the various sources of data?

The availability, quantity, and quality of data forms the foundation for analytics and AI. Knowing which data are involved helps in the planning of data capturing, mining, cleaning and processing. For example, in natural language processing, the choice of stop words could be complex and requires a nuanced understanding of what is being analyzed. The term "please" could be a stop word in most cases, but could be important in sentiment analysis. Another less explored research in knowledge building is to study the process across both online and face-to-face settings. This necessitates the integration of different modalities of data (text in the forum, voices in the classrooms), yet pursuing the same focus of analysis. This component of data-types, though normally relate to research, can create positive shifts in a usually uni-dimensional traditional classroom practice. The use of multimodal-data in the classroom can make teachers and students aware of new modes of interaction.

2b. Which levels and types of analysis are involved? (e.g., unit of analysis, level of analysis, temporal analysis)?

The study by Chen and Zhang (2016) illustrated how these questions guide their choice of analytics. Based on the design principles of knowledge building (epistemic agency and design mode of thinking), they proposed a choice-based, progress-oriented, multi-level, multi-unit, and multi-timescale analytics and illustrated the analytics with three case examples. In essence, choice-based analytics is to support epistemic agency of learners by empowering them with the choices of viewing and making use of analytics to advance their knowledge building practices, specifically, choices of working on emergent ideas, of pursuing themes of inquiry and higher-order conceptual structures, and discourse move. The analytics is progress-oriented because of the focused goals of improving the breadth and depth of ideas and the emergence of new strands of inquiry. It can involve multi-unit (e.g., analyzing individuals to a community), multi-level (e.g., relating ideas within a thread to across threads) and multi-timescale (e.g., temporal analysis of idea across time). Indeed, while the data from each student allow us to track their progress individually, the principle of collective cognitive responsibility to contribute to the advancement of collective knowledge means that group-level analyses are necessary. For the previous question, we discussed the integration of data across modalities. Within each modality, there is also a need to analyze data across levels. This is illustrated in Zhang and Chen's (2019) work on idea-thread analysis, where ideas across different threads are tracked to provide a holistic and coherent visualization of how ideas develop within a community.

There is a growing interest in temporal analytics (Knight, Wise, Chen, & Cheng, 2015) as it can help to trace interactions or development of ideas against time to gain deeper insights into what is going on within a discourse. Reimann (2009) argued that temporal analysis is important because the traditional notion of "independent measures" may not be immutable throughout a discourse supported by CSCL. By examining the entire discourse and focusing on certain features, the temporal details collected at the micro-level across time can be examined with the underlying theory operating at a macro level (Mercer, 2008). In addition to the KBDeX (Oshima et al., 2012), there are other methods and tools (e.g., SNAPP; Bakharia & Dawson, 2011) that can work as near real-time interaction diagnostic tool for social network analysis.

2c. What is the nature of the analytics / AI? (e.g., descriptive, diagnostic, predictive, prescriptive, reflective) How are the results of the analytics / AI presented?

Currently, the suite of built-in analytics in Knowledge Forum provides descriptive information as the foundation (e.g., online activity across time). But it is also critical to consider how such information can be used. For example, if the use of scaffolds by students is coupled with reflective activities with the students (Hong et al., 2015), the analytics can serve the reflective function. The information on social network analysis can be diagnostic, in the sense of diagnosing whether there are students who are disengaged, or there are cliques within a class. The study by Lee and Tan (2017), to some extent, predicts which ideas are promising, based on the trend of betweenness centrality values of notes up to the time of analysis. Thus, it is not simply the consideration of how the results are presented, but how they are used. The prescriptive function is less compatible with knowledge building principles since the student's agency is prized.

2d. Who is the target audience of the results (students, teachers, researchers)?

The clarification of who the target audience could reflect the phase of the exploration of analytics. The ultimate goal, as what Chen and Zhang (2016) proposed, is to encourage student agency, thus having students as the target audience. Teachers, however, could use the analytics as information to provide scaffold or guidance to the students. Researchers' use of analytics usually reflects that the use of analytics is still being investigated.

What has not been explored is the adaptive intelligent support that initiates actions based on diagnostic outcomes. For instance, if the system detects that certain scaffolds have not been used after some time (and the normal model shows that students could have proceeded to rise above), there could be reflective prompts appearing for students to think about moving into another phase of idea building.

A pilot with multilevel multimodal data

As an illustration, we describe how the above questions were used to guide a recent experiment called *Student Design Studio* in which 37 students, aged 10-16, from 7 schools in Singapore, were brought together to tackle the real-world challenge of sustainable living. Working through the set of questions help us to decide on the data collection and the nature of analytics to consider.

1. Which principles of knowledge building is/are the focus?
   - Real ideas, authentic problem: Engaging students with a real-world problem for sustainable verticle farming in Singapore. With this as design principles, it is then our goal to get the analytics to provide indicators about how real or how authentic the students' ideas are. Questions such as "how close are they getting to understand the problem that actual scientists, activists, engineers are talking about?"; "how much are they engaging the "public" in this problem?
   - Epistemic agency: Students' awareness of their learning process, their knowledge growth, and their knowledge gaps. How are the AI-enabled analytics allowing students to access to an accurate picture of their idea growth and not just a "score" of their work?
   - KB discourse leading to Rise-above: Redefining the role of experts in the learning environment. How do the AI-analytic provides visualizations that bridge the expert-novice chasm and support the removal of the hierarchical concept of expert answering students questions or expert judging students' question, but having experts as part of the community.

   Which aspects of knowledge building are augmented?
   - Social: student motivated to adjust their social interaction to learn more.
   - Cognitive & Metacognitive: Reflect on learning, interaction and "thinking" pattern
   - Emotional: Self-awareness and monitoring of emotions when engaged in knowledge work. When putting together, how these multiple dimensions (social, cognition, meta-cognition, and emotions) provide students with a new understanding of their ability and contribution which is the essence of 21CC. How these new understand then give students, regardless of their ability and age, the confidence to continue to contribute, to ride on their strength but also to work on their weakness. E.g. one who is a stronger thinker (providing good resource) but another could be more reflective of the dynamic of the group and asking more question about what to do next and in totality, how such heightened awareness of these two students within the community provides a platform to democratize the learning process.

   How does this augmentation enable the advancement of knowledge building beyond the current methods?
   - We are exploring various psycho-socio dimensions of knowledge building as well as integrating online and face-to-face interaction data. We advocate that knowledge building pedagogy and technology shape the culture of learning in class then students should behave, think differently throughout the online, face-to-face and even out of the class environment. The limitation of understanding students' thought through their post is potentially broken down by the introduction of AI. However, human interaction of mind and action in a knowledge building environment is so complex that the analysis is only possible if we worked through the previous few questions in a deliberate, rigorous and expansive manner. The current state of work in this still requires extensive manual triangulation to establish a near-accurate characterization of these knowledge building processes.

2. Which types of data are involved? (e.g., text, social interactions, cognitive interactions, voice, video, multimodal)?
   - LA/AI to create a meaningful connection between students' knowledge in class with that in the real world. LA/AI to support students in seeing their work in class connected to that in the real world.
   - Visualization of students' vocabulary, their emotional states that reveal insights of the learning process that might not be obvious to the learner or the teacher (e.g. perplexity)
   - Information about the process of learners' thinking and knowledge formation as it happens in a synchronous and asynchronous environment.

- Physiological data of students of heart-rate to help them manage their various emotions, from academic emotion to epistemic emotion.
- Multimodal data in the form of audio, video (of various granularities), physiological data, were collected and the analyses were shared with students throughout the two-day event.

Which types of analytics / AI are used?

- Quantitative: Number of notes written, read, replied, build-on.(For group post – we take the total number of writings and readings for the level of online interaction.
- Structure of online interaction – build-on.
- Content analysis of online & offline interaction: The content analysis can complement the type and level of interaction than the quantitative analysis.
- Social network analysis of online interaction. SNA visualizes learning processes through group members' interaction; structure, flow, and processes of interaction (e.g. centrality).
- Continually seeking coherence is what is important the design and practice, what is sound practice according to the principles, and most importantly, what impact do we want to create (Align with Q1).

How are the results of the analytics / AI presented? Who use the results (students, teachers, researchers)?

- Visualisation and outcomes of learning made available to the teachers, students, for discussion and self-reflection and these visualizations will be the object of meta-discourse. For teachers, these analytics will be used as data to make decisions about future actions; for students, it could be a metacognitive activity.

This set of questions has helped the researchers in determining the source of data, type of data, target audience of analytics, and types of analysis to be conducted.

Conclusions

This short review and discussion show the emerging work in the knowledge building community in the use of analytics or AI to augment the knowledge building process. Knowledge building differentiates from other CSCL or constructivist pedagogies by engaging students directly in knowledge work. Our understanding and practices of knowledge building should also be advancing in a perpetual self-renewing way because knowledge creation is a future-oriented progressive endeavor that theoretically, should not have an end-point. Moving forward, we propose a set of questions to consider when developing and investigating the development of how knowledge building can be augmented by analytics and AI. This set of guiding questions is developed to first ask about the principles and aspects of knowledge building being investigated, and then the types of data and analytics or AI that will be used. By focusing on knowledge building principles is to avoid using AI to replace human intelligence in guiding knowledge building work or prescribing pre-determined actions, doing so will be running against the very purpose of principle-based approach and developing students' capacity in knowledge work. We recommend focusing on how human (students and teachers) could work in intellectual partnership with computers that generate timely insights from data, to engage in knowledge building more efficiently and effectively.

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Exploring the Rate of Growth in Lexical Richness, Spelling, and Conceptual Understanding through Knowledge Building: Analyses of Grade 1 to 5 Discourse

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Abstract: This study explored the rate of growth in lexical, orthographic, and conceptual knowledge through analyses of discourse data produced by the same 12 Grade students during the 2015-2020 school years. Data sources used in this study included 656 notes: 87 notes in Grade 1, 56 notes in Grade 2, 86 notes in Grade 3, 75 notes in Grade 4, and 352 notes in Grade 5. Overall, while there was a dramatic reduction in spelling errors in their second year, lexical and conceptual knowledge growth happened more gradually in the first two to three years, with accelerated growth from Grade 3 or 4. Individual-level analyses revealed a clear distinction between high and low achieving students. High achievers were successful in all aspects whereas low achievers misspelled the most, used the fewest number of words, and had the lower scores on a depth of understanding measure. Although further research to confirm this finding is required, the current study suggests that early language struggles need attention to achieve better outcomes in knowledge building classrooms.

Introduction

In typical classrooms, language and disciplinary education are often in separate processes. Language classrooms teach 'skills' and knowledge to become a better reader, writer, or speaker just as physics classrooms teach physics knowledge to become a better citizen or candidate for future job positions. This notion that students need to learn each subject in each separate classroom has long been a habitual practice for students, teachers, and educational policy makers across many parts of the globe.

In knowledge building classrooms, however, such divisions blur. Studies have reported impressive literacy advances despite the absence of direct language instruction. These include academic and domain vocabulary above grade levels (Khanlari, Zhu, & Scardamalia, 2019; Resendes, Chen, Acosta, & Scardamalia, 2013; Sun, Zhang, & Scardamalia, 2010a; Sun, Zhang, & Scardamalia, 2010b); reading and writing in early years (Pelletier, Reeve, & Halewood, 2006); higher scores on the vocabulary section of a standardized test (Scardamalia, Bereiter, Brett, Burtis, Calhoun, & Smith-Lea, 1992); discursive connectedness (Resendes et al., 2013); and graphical literacy (Gan, Scardamalia, Hong, & Zhang, 2010). The socio-cognitive nature of knowledge creation as well as use of real-world problems and authoritative resources situate language knowledge within its contexts, which is a requirement of language knowledge acquisition (Brown, Collins, & Duguid, 1989).

The present study aims to explore the extent of growth in language and conceptual understanding through analyses of Grade 1 to 5 discourse data produced the same students starting from the 2015-2016 school year. Although the link between two measures was previously indicated (Zhang & Sun, 2008), patterns of this parallel growth over years is limitedly known. One research question to be addressed in this study is, *What does rate of change in lexical, orthographic, and conceptual understanding look like over five years?* The major purpose of this study is to establish benchmark data for subsequent analyses on other language measures and experimental studies to test effects of interventions on students' literacy in English as a first and second language contexts.

Literacy Advances in Knowledge Building Classrooms

With its 12 principles, Knowledge Building pedagogy engages students in sustained idea development on topics of their interests (Scardamalia, 2003). Students' inquiry is centered on real-world problems and idea improvement through social negotiation between students who contribute to discussions with collective responsibility in mind. Individuals or groups of students enter their ideas on Knowledge Forum—software designed to support knowledge building discourse—with functions to write, build on, and annotate ideas, evaluate progress, using embedded learning analytic tools, and synthesize their ideas.

Literacy learning is a natural consequence of knowledge creation processes (Gan, Scardamalia, Hong, & Zhang, 2010; Pelletier et al., 2006; Scardamalia et al., 1992; Sun et al., 2010a, 2010b). Studies have shown evidence of increased use of general vocabulary, more sophisticated English vocabulary, academic vocabulary in Grade 4 (Sun et al., 2010a, 2010b). Sun et al (2010b) reported that students took self-directed efforts to engage with authentic materials that tend to surpass their current level of understanding with other students, spot unknown words and check the meanings, and actively used words they learned from discourse with their peers or materials they have used during the two-year period of their study. Such collaborative efforts were linked to more positive literacy outcomes. Similarly, Catalan secondary students who more actively engaged in theory building with their peers scored better on writing and reading comprehension measures (Manegre & Gutiérrez-Colón, 2019).

Past literature has also reported that students showed evidence of using academic and domain-specific vocabulary across different subject areas and beyond their grade levels. Building onto a pilot study on Grade 1 students' cross-domain word use (Khanlari, Zhu, Costa, and Scardamalia, 2018), Khanlari et al. (2019) have shown that Grade 1 students discussed topics that are covered in Grade 1 to 6 grade curriculum and Grade 4 students on topics covered in Grade 2 to 9 curriculum. Grade 2 students used a greater number of domain-specific words beyond their grade level (Resendes et al., 2013; Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015) and more semantically related words from the previous year (Resendes et al., 2013). Sun et al. (2010a) also showed that Grade 4 students covered all terms related to the topic of discussion expected to be used by not only the same grade or lower students but also those in upper grade levels (Grade 8). In the same year, they (2010b) also found that nearly 90% of the words Grade 4 students have used was the same or lower grade level vocabulary and about 70% of domain-specific terms they used exceeded the grade level. These studies indicate that even young graders are capable of surpassing subject boundaries, and this impressive achievement continues into later grades with a greater range of vocabulary they productively use. As early as kindergarten, students used Knowledge Forum to discuss real-world problems they were interested in exploring and showed improvements in reading and writing measures (Pelletier et al., 2006).

The purposeful aim of engaging learners in knowledge creation, in a way that highly resembles a scientific community, naturally encourages them to read intensively to solve problems and advance shared community knowledge (Zhang & Sun, 2011), using a wealth of vocabulary in content areas (Resendes et al., 2013). In fact, elementary graders read and wrote more notes as they progress through grades (Sun et al., 2010b), produced a greater number of texts within a short amount of time that exceeded the average of high school students in America, and scored significantly higher on the vocabulary subsection of a standardized test (Scardamalia et al., 1992). Even without direct language instruction on scientific writing, students engaged in 'ideational writing' which marked higher scores on quality of texts and coherence than students who followed a general inquiry-based approach (Chuy, Scardamalia, & Bereiter, 2011).

Past knowledge building research indicate that literacy advances are closely connected with conceptual growth. Zhang and Sun (2008) reported that a greater effort of reading and writing was related to a greater understanding of a scientific concept. As the total number of general words, academic words, and the total as well as unique domain-specific words increased, students' understanding of light has also increased. Use of more advanced words was also positively correlated with their understanding at a significant level. Similarly, Sun et al., (2010b) showed that as students used more general, domain-specific, and academic words, ideas contained in their notes became more complex. Use of knowledge building analytic tools to reflect on their vocabulary and discourse moves facilitates more diverse use of English words as well as a deeper understanding of scientific concepts (Resendes et al., 2013). These studies suggest that students could advance their linguistic knowledge and conceptual understanding simultaneously as they progress through their grades, building on knowledge creation experiences.

Methods

Data Sources and Analysis

Discourse data produced by the same 12 students archived in three Knowledge Forum online databases was used for data analyses. Although the discourse data were produced over five years starting from the 2015-2016 school year, it is important to note that the actual amount of time students engaged in idea building on Knowledge Forum varied as indicated below. They have produced 656 notes in total on different topics: Grade 1 (8 days)—87 notes on butterfly life cycle and water movement; Grade 2 (2 days)—56 notes on salmon life cycle; Grade 3 (1 days)—86 notes on animal vision; Grade 4 (3 days)—75 notes on air and water; Grade 5 (8 days)—352 notes on moon.

In the knowledge building classrooms, students identified authentic, real-world problems they were interested in exploring and engaged in idea-deepening discussions through formulating questions, generating and testing theories, supporting/abandoning theories by doing research and experiments during face-to-face discussions called "KB Talks" as well as in writing on Knowledge Forum. When they entered their ideas on Knowledge Forum, teachers encourage students to express their ideas without being overly concerned with grammar and spelling.

For data cleaning, we built a program for spell checking and word counting purposes. The program calls the open-source Hunspell static library (http://hunspell.github.io/) to match words used in Knowledge Forum databases with a list of English vocabulary contained in the library. Words not found in the library were flagged as errors. By the term "errors" here we refer to all misspelled words due to a lack of orthographic knowledge as well as pure mistakes. Spacing errors (e.g. I likethe idea) were also flagged, and we manually corrected them without correcting misspelled words. Illegible words, students' and teachers' names, and scaffolds were removed.

Different measures used in this study are as follows:

1. Misspelled Words: Following the correction of spacing errors, we ran the program again to calculate the total number of misspelled words for each grade. Words not detected as errors by the program due to a lack of syntactic knowledge (e.g. "I don't no") were manually counted and corrected. Misspellings due to immature grammatical knowledge were considered as grammatical errors and omitted from the total number of errors. For example, misspellings with an indication of correct understanding of grammatical concepts (e.g. I no how water turns into snow) were considered as spelling errors, whereas words that follow general conventions but contain grammatical errors (e.g. "withstanded") were excluded from the total. However, these words were included in the total and unique number of words. No grammatical errors that affect spelling were corrected (e.g. "is fising cils them?" was corrected to "is fishing kills them?").
2. Lexical Profile: After counting misspellings, we corrected spelling errors manually. We then used the same program to measure growth in lexical richness by calculating the numbers of the first and second 1,000 most frequent English words, other words beyond the high frequency range, domain-specific vocabulary, and academic vocabulary. The first 2,000 words account for a large proportion of words used in texts (Nation, 2001). Words with lower frequency ranks are an indicator of more sophisticated vocabulary (Laufer & Nation, 1995). For the high frequency words, we used the top 20,000 lemmas with their word families from the Corpus of Contemporary American English (COCA; Davies 2008-). COCA is the most up-to-date corpora with word families and part-of-speech tags that enable accurate analyses of word uses. To measure academic vocabulary, we used the Academic Word List (AWL; Coxhead, 2000) which contains 570 academic words with grammatical variations. For domain-specific words, we consulted the Ontario Science Curriculum documents to identify words specifically used in subject areas.
3. Depth of Understanding: We measured depth of conceptual understanding in theorizing notes using epistemic complexity and scientificness schemes developed by Zhang, Scardamalia, Lamon, Messina, and Reeve (2007). The first author identified "theorizing" notes, using ways of contributing inventory (see Chuy, Zhang, Resendes, Scardamalia, and Bereiter, 2011). Theorizing notes include students' ideas to advance theory building on scientific concepts. These notes, especially when elaborated, contain examples, evidence, and findings from authoritative resources and student-directed experiments. In total, the first author identified 334 theorizing notes: 44 notes in Grade 1, 23 notes in Grade 2, 28 notes in Grade 3, 52 notes in Grade 4, and 187 notes in Grade 5 in data produced by the final 12 students. Epistemic complexity has been used to measure the level of complexity in students' cognitive efforts to describe or explain scientific concepts developed while scientificness of ideas measures the level of accuracy in students' descriptions or explanations of scientific concepts (Zhang & Sun, 2008). Scores measured based on each of the four-point scales were then multiplied to obtain a composite value (e.g. scoring 3 for epistemic complexity and 3 for scientificness means scoring 9 for the note) because the level of complexity in their ideas affects our interpretation of accuracy in students' conceptual understanding (Zhang & Sun, 2008). After the first author rated all theorizing notes, another researcher used the same scale to rate the same notes. We reached an agreement rate of 98% on depth of understanding after we discussed over our choices.

Results

Depth of Understanding

Table 1 and Figure 1 shows average scores of a depth of understanding measure for each student. For most students, there was little difference between Grade 1 and 2. Scores slightly increased from Grade 3, followed by the greatest improvement at Grade 4 and a drop at Grade 5. Two initially low achieving students (st1, 2), two in the middle (st5, 8), and two initial high achievers (st6, 9) achieved particularly high scores at Grade 4. At Grade 5, St1, 2, 5, 8, 12 were high scorers.

Table 1. Average Depth of Understanding Scores per Student.

Grade	median	St1	St2	St3	St4	St5	St6	St7	St8	St9	St10	St11	St12
1	2.17	2.17	1.90	2.00	1.25	2.00	3.00	2.17	2.50	4.00	3.50	2.00	3.25
2	2.00	3.00	2.00	2.00	2.00	3.75	2.00	2.00	2.00	4.50	3.50	2.00	2.00
3	2.63	2.50	2.50	2.00	2.00	3.00	2.00	2.50	3.00	2.75	3.25	3.50	3.00
4	5.50	6.38	6.80	2.80	4.00	7.25	7.00	5.00	7.40	6.00	2.67	4.50	3.67
5	3.80	4.18	3.71	2.15	3.27	4.93	3.56	4.56	4.86	3.17	4.13	3.29	3.89

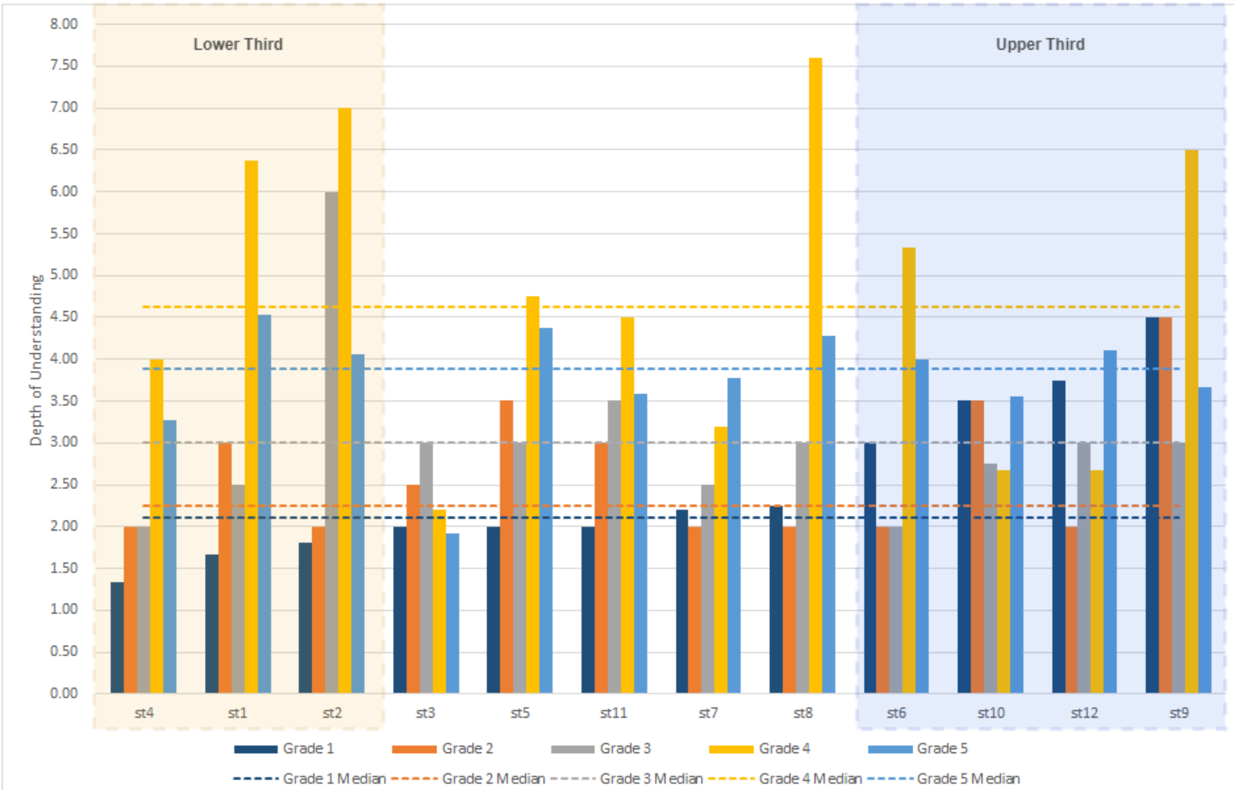

Figure 1. Average Depth of Understanding Scores per Student.

Vocabulary

Table 2 shows percentages of types of words each student had used in their discourse. At Grade 1 their productive vocabulary mostly consisted of the first 1,000 words and domain-specific words. However, numbers started distributing more across types from Grade 3 or 4 for many students. At Grade 5, St1, 2, 5, 6, 7, 10 had smaller proportions of the first 1,000 words and larger percentages of the second 1,000 words and beyond than other students. This indicates that these students productively used more advanced words in their notes. As Tables 3 and 4 show, four of the students (St1, 2, 5, 10) produced an exceptionally high number of total and unique general English words at Grade 5. Together, these results suggest that the four students were exceling other students in terms of both quantity and quality of their lexical knowledge. For St3, 4, and 8, over 75% of their productive vocabulary was in the first 1,000-word group, and the total and unique word counts were substantially lower than the high achievers.

Table 2. Lexical Frequency Profiles for each Student.

	St1					St2					St3				
Grade	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1st 1,000	76.47%	75.00%	80.43%	83.91%	68.08%	65.71%	84.62%	61.54%	78.26%	71.58%	72.73%	84.00%	80.95%	84.85%	75.58%
2nd 1,000	0.00%	3.57%	0.00%	1.15%	4.23%	5.71%	0.00%	2.56%	0.00%	6.56%	9.09%	4.00%	4.76%	0.00%	0.00%
Others	2.94%	7.14%	4.35%	2.30%	7.98%	8.57%	7.69%	10.26%	6.52%	7.65%	9.09%	8.00%	0.00%	0.00%	4.65%
Academic	0.00%	0.00%	0.00%	1.15%	4.69%	0.00%	0.00%	0.00%	0.00%	1.09%	0.00%	0.00%	0.00%	0.00%	0.00%
Domain	20.59%	14.29%	15.22%	11.49%	15.02%	20.00%	7.69%	25.64%	15.22%	13.11%	9.09%	4.00%	14.29%	15.15%	19.77%

	St4					St5					St6				
Grade	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1st 1,000	78.95%	84.21%	64.71%	73.08%	75.29%	68.75%	72.73%	74.29%	79.03%	65.64%	78.95%	69.23%	80.00%	82.61%	70.37%
2nd 1,000	0.00%	0.00%	0.00%	3.85%	1.18%	6.25%	9.09%	2.86%	1.61%	5.64%	5.26%	7.69%	0.00%	4.35%	5.56%
Others	0.00%	5.26%	8.82%	7.69%	2.35%	0.00%	0.00%	0.00%	0.00%	8.72%	0.00%	0.00%	4.00%	2.17%	0.00%
Academic	0.00%	0.00%	0.00%	0.00%	1.18%	0.00%	0.00%	0.00%	3.23%	1.54%	0.00%	0.00%	4.00%	0.00%	1.85%
Domain	21.05%	10.53%	26.47%	15.38%	20.00%	25.00%	18.18%	22.86%	16.13%	18.46%	15.79%	23.08%	12.00%	10.87%	22.22%

	St7					St8					St9				
Grade	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1st 1,000	66.67%	72.00%	61.54%	69.23%	69.90%	61.76%	89.47%	64.29%	80.00%	76.60%	67.50%	80.00%	67.39%	72.73%	76.67%
2nd 1,000	0.00%	8.00%	7.69%	0.00%	3.88%	2.94%	0.00%	7.14%	0.00%	1.06%	2.50%	0.00%	8.70%	4.55%	2.50%
Others	3.33%	4.00%	7.69%	7.69%	4.85%	2.94%	5.26%	10.71%	4.62%	1.06%	0.00%	0.00%	4.35%	2.27%	4.17%
Academic	0.00%	0.00%	0.00%	1.92%	1.94%	0.00%	0.00%	0.00%	1.54%	3.19%	2.50%	4.00%	2.17%	0.00%	1.67%
Domain	30.00%	16.00%	23.08%	21.15%	19.42%	32.35%	5.26%	17.86%	13.85%	18.09%	27.50%	16.00%	17.39%	20.45%	15.00%

	St10					St11					St12				
Grade	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1st 1,000	91.30%	75.86%	72.73%	72.41%	67.54%	81.82%	85.71%	75.00%	73.08%	73.02%	82.61%	83.33%	61.90%	78.26%	74.39%
2nd 1,000	0.00%	3.45%	4.55%	3.45%	10.99%	0.00%	4.76%	0.00%	3.85%	6.35%	4.35%	5.56%	4.76%	0.00%	1.22%
Others	8.70%	0.00%	4.55%	0.00%	6.81%	0.00%	0.00%	5.56%	3.85%	0.79%	0.00%	0.00%	4.76%	4.35%	6.10%
Academic	0.00%	0.00%	0.00%	0.00%	1.57%	0.00%	0.00%	0.00%	0.00%	1.59%	0.00%	0.00%	0.00%	0.00%	0.00%
Domain	0.00%	20.69%	18.18%	24.14%	13.09%	18.18%	9.52%	19.44%	19.23%	18.25%	13.04%	11.11%	28.57%	17.39%	18.29%

Note. 1st 1,000 = the 1st 1,000 most frequent words; 2nd 1,000 = the 2nd 1,000 most frequent words; others = words ranked beyond the first 2,000 words; Academic = academic words; Domain = domain-specific words.

Table 3. Total Number of Words Used by each Student.

Grade	St1	St2	St3	St4	St5	St6	St7	St8	St9	St10	St11	St12
1	49	65	12	23	19	27	41	46	62	27	23	42
2	36	39	35	22	32	12	30	20	35	35	26	20
3	56	52	32	36	36	28	29	39	58	81	42	25
4	187	89	43	38	101	74	102	139	180	36	36	27
5	640	508	163	181	703	155	246	217	266	734	334	167

Table 4. Unique Number of Words Used by each Student.

Grade	St1	St2	St3	St4	St5	St6	St7	St8	St9	St10	St11	St12
1	33	35	11	18	17	19	31	34	40	23	11	22
2	26	25	24	18	23	12	24	18	24	29	21	18
3	47	39	21	33	33	25	26	29	42	42	34	21
4	81	41	31	26	62	49	48	65	84	28	25	23
5	217	208	90	85	199	54	104	88	125	199	129	81

Further analysis of notes revealed that in the first three years words used to describe something or ask for descriptions (e.g. they, what) most frequently appeared in their notes. At Grade 4, words for reasoning or explanation (e.g. because, why) started taking a larger proportion of students' vocabulary than the words to provide or request descriptions. This is reasonable considering initial students' discourse mainly focused on building on facts, rather than explanation, which then moved into ideas requiring more complex thoughts in later grades.

Except for St9, students did not use any academic words until Grade 4. St9 used words such as *survive* (Grade 1), *release* (Grade 2), *similar* (Grade 3), *definitely* (Grade 5), and *theory* (Grade 5). Academic words were either related to topics of discourse (e.g. core, phase, vision, layer, revolution) or words more generally used in academic contexts (e.g. percentage, research, finally, eventually, estimate). Although St1 had used no academic words until Grade 4, this student used a greater number of words (10 words) at Grade 5 than other students (2 words at maximum).

As reported in past studies (xx), students used domain-specific words expected above their grade levels. Examples are: Grade 1—*liquid* (Grade 2), *flowers* (Grade 6), *maple* (Grade 3), *pollen* (Grade 3); Grade 2—*rocks* (Grade 4), *predators* (Grade 6), *explosions* (Grade 4); Grade 3—*animals* (Grade 6), *predators* (Grade 6); Grade 4—*particles* (Grade 9), *evaporate* (Grade 5), *bacteria* (Grade 6), *electrons* (Grade 9); Grade 5—*asteroids* (Grade 6), *tides* (Grade 8), *solar/lunar eclipses* (Grade 6). While the same or lower-grade level words occupied their domain-specific vocabulary in early years, the proportion of unique above-grade level words became larger at Grade 4 (See Table 5).

Table 5. Percentages of Unique Domain-Specific Vocabulary Expected for the Same, below, or above Grade Levels.

			Grade		
Grade Levels	1	2	3	4	5
Same or Below	62.86%	84.21%	87.76%	26.53%	27.55%
Above	37.14%	15.79%	12.24%	73.47%	72.45%

Spelling Errors

For misspellings, simply counting the number of misspellings does not reveal meaningful results because upper grade students had written more notes and words and the time students had spent for writing on Knowledge Forum varied. Therefore, we calculated the percentages of the misspelled words by dividing the number of misspelled words by the total number of words students had written to have relative values (Table 6 and Figure 2).

This calculation revealed that almost all students had the greatest numbers of misspellings at Grade 1, which then dramatically dropped as they progressed through grades. This is consistent with a study that reported a fewer number of misspelling as a student's lexical knowledge increases (Flor et al., 2015). Three initial low achievers (St3, 4, 7) still used the greatest number of misspelled words at Grade 5. St12, a initial high achieving student, used the fourth greatest number of errors at Grade 5 and misspelled almost equally as the initial low achievers at Grade 3. One student in the lower-third (St11), one student in the middle (St5), and three students in the upper-third (St1, 2, 10) had the fewest number of errors at Grade 5.

Table 6. Percentages of Misspelled Words per Student.

Grade	median	St1	St2	St3	St4	St5	St6	St7	St8	St9	St10	St11	St12
1	29.92%	16.33%	9.23%	58.33%	52.17%	31.58%	40.74%	51.22%	28.26%	22.58%	11.11%	47.83%	21.43%
2	5.98%	5.56%	7.69%	0.00%	9.09%	6.25%	8.33%	0.00%	10.00%	0.00%	5.71%	3.85%	10.00%
3	5.36%	3.57%	1.92%	21.88%	25.00%	5.56%	14.29%	0.00%	5.13%	5.17%	6.17%	4.76%	44.00%
4	4.01%	3.21%	0.00%	11.63%	18.42%	2.97%	5.41%	8.82%	4.32%	3.33%	11.11%	2.78%	3.70%
5	2.44%	1.88%	0.98%	4.29%	11.05%	1.99%	2.58%	5.28%	2.30%	3.38%	0.14%	1.80%	3.59%

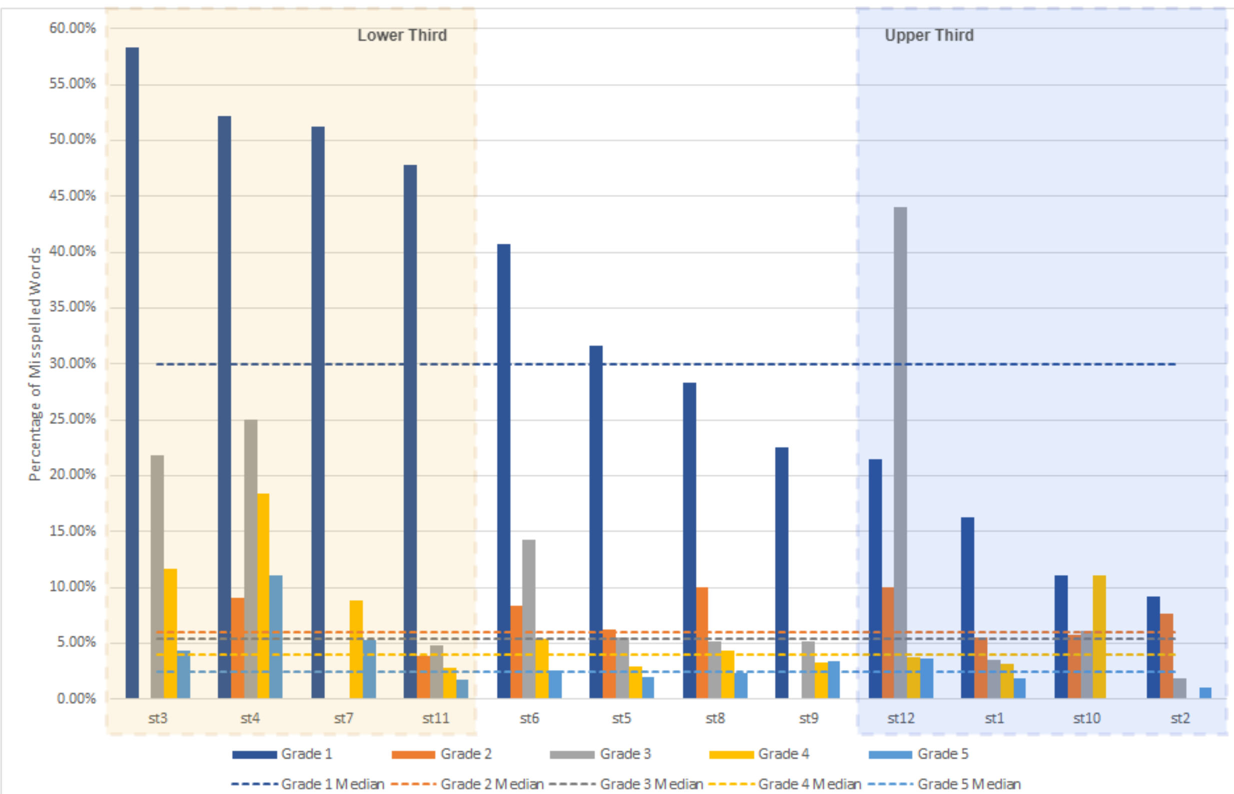

Figure 2. Percentages of Misspelled Words per Student.

Table 7 shows the first 30 most frequently misspelled words for each grade. Lower graders tended to misspell more general words (e.g. thay, yoos, becuse, litol). Most errors frequently seen in lower grades disappeared naturally at Grade 4 or 5, but the students then had spelling errors in less frequent general words (e.g. probbibly, piece, mabey) as well as domain-specific words (e.g. gibos, crators, avaporate).

Spelling errors of certain words (e.g. thye, bacuse, maby, brobibly) continued being misspelled in the same or different forms in later grades (e.g. thay, beacuse, mabey, probobly). Individual-based analysis revealed that this was more evident for low achievers. For example, St3 and St4 had words such as *thay [they], tay [they],* and *thayr [they're]*, and *wots [what's]* at Grade 1, and these still existed in their notes in the same (thay) or different (thare [they're], wats [what's]) forms. Similarly, St12 had various forms of errors continuing into later grades for *they* (e.g. thay, thar, tarselves) and *make* (e.g. mak, maks). With an increasing number of using *maybe*, *because*, and *probably* as their notes contained more complex ideas, persistent errors on these words throughout the last three years became more evident for this group compared to others. Similar tendency was also seen for other students; however, for most misspelled *they* disappeared at Grade 2. Likewise, *maybe* and *because* errors disappeared by Grade 4, except for St2 who spelled *probaly* at Grade 2 and continued misspelled it (proboly) at Grade 5.

Table 7. the First 30 Most Frequently Misspelled Words for each Grade

Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
Word	Count	Word	Count	Word	Count	Word	Count	Word	Count
thay *	17	aftr	1	beacuse *	3	particals	6	gibous	4
babys *	5	babys *	1	breth	3	rippels	5	atmospere	3
ther	5	bacuse *	1	thay *	3	becase *	2	geting	3
thik	4	difrint *	1	foxs	2	sirvive	2	diffrent *	3
maebee *	3	exploshons	1	tink	2	thay *	2	probobly *	2
thye *	3	famaliy	1	coler	2	avaporate	2	colided	2
wat *	3	fertaliser	1	babys *	1	breth	1	gibos	2
blud	3	junp	1	coulr	1	breate	1	peice	2
thred	3	ley	1	bottem	1	los	1	crators	2
thare *	3	meen	1	maby *	1	probbibly	1	coalidide	2
relatevs	2	preditors	1	rily	1	brobibly	1	luner	2
catapilrs	2	pretotors	1	wats *	1	beacse *	1	alinment	2
wut	2	probaly *	1	beder	1	gasses	1	somthing	2
thigs	2	salk	1	litol	1	crubled	1	divit	2
tha	2	thay *	1	thare *	1	pacticals	1	eclipes	2
ked	2	wate	1	realy	1	elechons	1	lunur	2
thrad	2	wiil	1	breeth	1	mabey *	1	finnaly	1
leevs	2			sunglassis	1	rippells	1	pecentage	1
yoos	2			evry	1	somene	1	atmospsere	1
tec	2			predader	1	because *	1	sheild	1
butterflys	1			cheetas	1	hevey	1	eclipsise	1
thinc	1			predetors	1	minrels	1	proboly *	1
themselvs	1			bairs	1	anamels	1	antartica	1
coccoon	1			reasins	1	deffintley *	1	smaler	1
weeve	1			sarks	1	prusser	1	importent	1
reaiativs	1			blak	1	tate	1	mountins	1
fiy	1			similer	1	inportent	1	callled	1
suk	1			becuse *	1	ulimeted	1	atmophere	1
tay *	1			becaus *	1	oxagen	1	maeby *	1
lik	1			searshd	1	diffrent *	1	colided	1

Note. Only 17 words were misspelled at Grade 2. Words with asterisks indicate common errors that continuously appeared in later grades.

Discussion and Conclusions

The current study explored the extent of change in vocabulary richness, spelling, and depth of understanding scientific concepts by analysing discourse data produced by 12 students during five school years. Overall, while there was a dramatic reduction in spelling errors in their second year, lexical diversity and conceptual knowledge grew more gradually in the first two to three years, with accelerated growth from the third or fourth year. According to Chall's (1996) model of reading development, students engage in "learning to read" in the first three years and then move into the next "reading to learn" stage in which students actively construct conceptual and lexical knowledge through reading. This gap is also where the "fourth-grade slump" occurs (Chall & Jacobs, 2003); however, students in knowledge building classrooms seemed to transition this gap smoothly, scoring the highest on depth of understanding measure and starting to use more sophisticated vocabulary at Grade 4. Chall and Jacobs suggested that a fourth-grade slump is caused by students avoiding reading resources that require more cognitive effort and consequently losing chances to encounter more literary, abstract, and sophisticated vocabulary that helps them comprehend higher-level texts. In knowledge building classrooms students are encouraged to read authentic resources and use words that are often beyond their grade levels in corporation with other students. As even Grade 1 students use vocabulary higher than their grade level (Khanlari et al. 2018, 2019), students engage in knowledge creation might slowly build strong foundation in the first two to three years to make a smooth transition between the two stages.

Individual-level analyses revealed a clear distinction between high and low achieving students. High achievers (St1, 2, 5, 10) were successful in all aspects, having the smallest percentage of errors, the greatest number of words, the most sophisticated vocabulary, and a better understanding of concepts than other students. On the other hand, low achievers (St3, 4) misspelled the most, used the fewest number of words, and had the lower scores on the depth of understanding measure. It is also worth mentioning that, unlike lexical and conceptual measures, early achievement on spelling might affect achievement later. For example, three students who misspelled the most (St3, 4, 7) and another three who misspelled the least (St1, 2, 10) in their first year followed the same trends after four years. By looking at actual words students had misspelled over time, it was also evident that these low achieving students repeatedly misspelled high frequent words over years whereas errors in the three high achievers' notes switched to less frequent words or domain-specific words as they progressed. This suggests a link between lexical, orthographic, and conceptual knowledge advances and possibility that the initial tendency continues if there is no intervention. Literature suggests that spelling is indeed linked to use of advanced words (Flor et al., 2015) and is also a key factor of understanding highly complex texts (Chall & Jacobs, 2003). It is possible that students with less language knowledge successfully comprehend texts (Carroll, 1977) and explain in a simple language, effectively using contextual information, own reasoning, and/or conceptual understanding. Indeed, St6, 8, and 12 had a high number of errors and less sophisticated vocabulary showed a similar level of conceptual understanding as the high achieving students at Grade 5. Nevertheless, literacy advances are crucial in schooling, and this issue should not be abandoned. Although further research to confirm this finding is required, the current study suggests that early language struggles need attention to achieve better outcomes in knowledge building classrooms.

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Pedagogical Paradigms: Transformational Professional Online Learning

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Abstract: Online learning courses have been mandated for high school students in the province of Ontario, and in light of the COVID-19 situation, much of the K-12 moved to online learning opportunities. It is generally understood that the initial offering of courses did not meet the needs of the learners. In an effort to provide an alternate way forward, the Fully Online Learning Community model (FOLC) was offered through the Ontario College of Teachers (OCT) as a transitional model for designers/teachers to produce learning environments that were more suited to learners requirements. The model integrates a Problem Based Learning (PBL) orientation which is situated within a fully online environment. The project reported upon here was conducted as a 'purposeful action research' study following teams of instructional designers/teachers and OCT staffers as they undertook the design and implementation of Additional Qualification courses using the FOLC Model. In this article, data derived from posts in Knowledge Forum were analysed. Interactions with project participants showed their desire to transform their understanding of learning within fully online community contexts. However their understanding of what was required for course revision was in tension with the underlying philosophy of the FOLC model.

Introduction

Opportunities to engage in potentially transformative professional learning regarding teaching within the public domain are rare, and to have these opportunities occur within online learning spaces is even rarer. This article concerns a group of instructional designers and teachers who participated in an extensive curriculum development project. The participants were brought together as they were interested in exploring an alternative conception of online Additional Qualifications (AQ) courses, professional learning courses sanctioned by the Ontario College of Teachers, within the context of fully online learning community environments. More than 30 participants engaged in a collaborative action research project over the course of approximately six months. The project consisted of a series of workshops and course design work supported by communication in Slack and reflection in Knowledge Forum (referred to here as WebKF) in order to examine the redesign of AQ courses as the current format has generally been viewed as being ineffective for the purposes of transforming the teaching profession.

The focus of the collaborative action research project centred on the Fully Online Learning Community (FOLC) model (vanOostveen, DiGiuseppe, Barber, Blayone & Childs, 2016). Environments that are constructed around the FOLC model are conceptualized as “democratized learning communities that reduce transactional distance (Moore, 1997) between learners and educators, incorporate authentic assessment, and encourage negotiated technology affordances and cognitive outcomes while distributing responsibility for constructive criticality” (p.1). In other words, designing FOLC environments facilitates movement from teacher-directed, closed-ended spaces to those that can be characterized as student-driven and open-ended (Coomey and Stephenson, 2001). The project was initiated as a contribution to provincial capacity building in the K-12 education sector and predates the COVID-19 situation by one year. This article provides an initial report on the analysis of the data collected throughout the project with a particular focus on the data derived from the use of WebKF within the project.

Literature Review

Online learning courses (prior to the COVID-19 situation) have recently been mandated for secondary school students in the province of Ontario. However, the design, pedagogy and format of these courses have not been specified. While there are few details, it is generally understood by many practising teachers that the initial offering of these distance courses may not meet the needs of the learners. Historically, there is evidence that students learning online often feel isolated, leading to attrition rates up to 20% higher than face-to-face learning (Angelino, Williams & Natvig, 2007). The expectations and demands placed on online learners are increasing (Kizilcec & Halawa, 2015) and changes in student-centred web-based learning environments often require learners to be more independent and better problem-solvers (Dabbagh & Kitsantis, 2004). To counter this potential for social isolation in online learning, researchers at Ontario Tech have developed a collaborative, problem-based learning FOLC model that provides the theoretical framework for this research.

FOLC Model

The FOLC model is a direct response to the limitations of distance learning, MOOCs and realist epistemologies (van Oostveen, DiGiuseppe, Barber, Blayone, & Childs, 2016). The FOLC model embraces the constructivist notion that reality, including virtual reality, is something that is created, rather than discovered (Johnson, 2014), and it incorporates the idea that communities are dynamic (not static) "co-creations." Focused on facilitating the development of critical thinking, problem-solving, communication, creativity and collaboration skills in current online environments, the FOLC model also focusses on the development of 4th Industrial Revolution competencies desired by (international and local) economic and government organizations such as the World Economic Forum (2016), the Conference Board of Canada (2016) and the Ontario Ministry of Advanced Education and Skills Development (2016). Importantly, FOLC's activity, control and community orientations are also consistent with Human Rights Education (Tibbitts, 2005; Tibbitts & Kirchschlaeger, 2010); Social Justice Education (Grant & Gibson, 2013); and other forms of transformative, emancipatory, and socially-engaged learning. Several specific conditions fostering transformative learning identified by Taylor (2007, 2008, 2016), and strongly aligned with FOLC, include:

- An environment that promotes a sense of safety, openness, and trust, encouraging the sharing of emotions as preparation for critical reflection.
- Activities that facilitate the exploration of divergent perspectives, problem-solving, and critical thinking.
- A community that promotes each member's sense of autonomy, engagement, and collaboration.
- The use of feedback, self-assessment, and self-dialogue that are used to assist the process of transformative learning.

While the FOLC is a derivative of the Community of Inquiry or COI model, there are some significant differences. The FOLC incorporates Social (SP) and Cognitive Presence (CP). It subsumes Teacher Presence (TP) fully within the other presences. This move, rooted in a democratized approach to learning, places greater emphasis on the community and the nurturing of learner empowerment and social engagement. Secondly, FOLC introduces the "digital space" as a dynamic, negotiated, co-constructed contextual construct with the potential to extend the scope and amplify the richness of SP and CP. Thirdly, FOLC is conceptually inclusive, explicitly incorporating several subsidiary models, which address additional "layers" of the learning experience (e.g., learning activities and goals, digital devices and competencies, responsibility and control, community formation and assessment). To date, in the originating context of UOIT, the following sub-models have been used to enrich and adapt FOLC in specific contexts of practice and research:

- Problem and inquiry-based learning (Savin-Baden, 2000, 2007)
- General Technology Competency and Use (Desjardins, 2005; Desjardins, Lacasse, & Belair, 2001; Desjardins & van Oostveen, 2015)
- Teaching Learning Paradigm (Coomey & Stephenson, 2001; Layne & Ice, 2014)
- Community of Practice (Lave, 1991; Wenger, 1998; Wenger & Snyder, 2000)
- Transactional Distance (Moore, 1993)

Social Presence

Within CoI research, SP was conceptualized and empirically explored through discourse analysis of asynchronous (text-based) discussion transcripts. This methodology demonstrated the ability of text-based computer conferencing to support "affective interpersonal interactions," a sense of immediacy and group cohesiveness (Rourke, Anderson, Garrison, & Archer, 1999). SP was defined originally as "the ability of learners to project themselves socially and emotionally in a community of inquiry" (Rourke et al., 1999) or as "real people" (with their full personality) through digital technology (Garrison et al., 2000). Subsequent research triggered a redefinition of SP as "the ability of participants to identify with the group or course of study, communicate purposefully in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities" (p. 34).

The synergistic dimensions of the Fully Online Learning Community (FOLC) model are conceptualized as Social Presence (SP) and Cognitive Presence (CP) occurring primarily within a Digital Space comprised of community-selected, asynchronous and synchronous affordances. Successful Collaborative Learning occurs at the intersection of these dimensions as the learners develop their sense of community, and requisite digital competencies are applied to support critical inquiry. Recognizing that not all social and cognitive interactions are digitally mediated, even in fully online courses/programs, FOLC may be adapted to hybrid-learning environments by strategically resizing/repositioning the Digital Space in relation to SP and CP shifts emphasis from interpersonal relationships to the creation of a cohesive learning community.

The FOLC model finds conceptual alignment with the current CoI definition of SP. At the same time, the issue of whether learners in an online environment are perceived as "real"—based on the work of Gunawardena (1995)—continues to inform FOLC's conceptualization and empirical exploration of SP (van Oostveen, Childs, Clarkson, & Flynn, 2015) because this perception is thought to influence the quality of relationships in a learning community.

The FOLC model focuses the attention of the community toward the building of relationships and the degree to which these environments can be personalized (Hod, Bielaczyc & Ben-Zvi, 2018) so that skills and competencies such as critical thinking can be "developed through becoming part of a community that appreciates and values critical thinking" (Trninic, Swanson & Kapur, 2018).

Cognitive Presence

In the FOLC model, cognitive presence is envisioned as a "thoughtful, reflective and analytic" (Dannels, 2016) process that directs the quality and quantity of critical thinking, collaborative problem-solving, and construction of meaning that occurs during community member interactions. Cognitive presence reflects the quality and quantity of critical thinking, collaborative problem-solving, and construction of meaning occurring in community member interactions. It is based on the iterative relationship between personal understanding and shared dialogue (Garrison & Cleveland-Innes, 2005).

FOLC recognizes the merits of Dewey's model of Practical Inquiry (Dewey, 1933), particularly the focus on rigorous inquiry, and the responsibility of every learner to transform potentially useful ideas into socially contestable knowledge. However, FOLC is more flexible than this earlier model regarding what specific sub-models a particular learning community may wish to incorporate. To date, FOLC learning communities have incorporated: (a) Popper's Three Worlds model, which creates a conceptual space ("World Three") for publically contestable knowledge artefacts; (b) the constructivism-informed Science & Technology Education framework (Bencze, 2008); Problem-based Learning models and accompanying Problem-based Learning Objects (PBLOs) emphasizing the analysis of contexts rather than teacher-defined problems (vanOostveen, Desjardins & Bullock, 2018), and other socio-constructivist approaches, such as Knowledge Building (Scardamalia, 2002; Cacciamani, Cesareni, Martini, Ferrini & Fujita, 2012).

Digital Space

The CoI model views digital technologies and competencies as extraneous to the core model. It was thought that to include the digital context as a dimension would make the CoI model unreasonably complex. The FOLC model resists this reduction, conceptualizing the digital space as a key sub-context for immersive online learning. According to FOLC, SP and CP cannot be fully conceptualized without considering the mediating influences of the digital space (Blayone, vanOostveen, Barber, DiGiuseppe & Childs, 2016).

In FOLC learning environments, digital spaces are co-created by all members of a learning community. Typically, the learner/designer initially begins to define the space by posting videos (constructed as PBLOs) to YouTube and providing facilitated tutorial sessions in a browser-based, audio-video conferencing suite. Subsequently, when working collaboratively in small groups, Open Educational Resources (OER) and other web-based applications are chosen by the learners according to two specific principles: (a) resources used must be shareable, and (b) the URL for the site(s) must be provided to everyone in the learning community. The tools and applications selected incorporate a mixture of synchronous and asynchronous environments (including creative synchronous/asynchronous merging), allowing for greater clarity and effectiveness of the interactions than can be achieved using asynchronous technologies alone (Trevino, Lengel, & Daft, 1987; Rockinson-Szapkiw & Wendt, 2015).

In particular, the use of a browser-based audio-video conferencing tool, in which each individual is represented by a "real-time" (web-cam-generated) image, and by audio interactions through a microphone headset, provides a strong semblance of face-to-face interactions which allow participants to "present themselves to others as real people" (Garrison et al., 2000). The use of visual cues, such as facial expressions and body language; audio cues from direct speech; and the incorporation of text-based backchannels allow for the promotion of SP, community, and ultimately, collaborative learning (Rockinson-Szapkiw & Wendt, 2015).

Importantly, FOLC's digital space is an oftentimes unpredictable context for online learning. It is not a neutral space but rather a space inhabited by applications and platforms that shape interactions. Even platforms such as Facebook or LinkedIn may be chosen by learners owing to their level of comfort using the application. However, the discussion functionality was not designed for sustained collaborative inquiry, and therefore, limits are placed on

CP. In a FOLC environment, this situation becomes a learning experience rather than a situation to be avoided (Blayone, vanOostveen, Barber, DiGiuseppe & Childs, 2016).

Action Research

Carr and Kemmis (1986) agree that teachers are severely limited in the autonomy that they possess. "Teachers operate within hierarchically arranged institutions and the part they play in making decisions about such things as overall educational policy, the selection and training of new members, accountability procedures, and the general structure of the organizations in which they work is negligible" (p. 39). In order to make teaching a more professional activity, teachers must take advantage of existing opportunities to participate much more widely in the decision-making process. The challenge becomes one of attempting to engage teachers in authentic teacher professional learning which reflects the characteristics noted above. In the estimation of these authors, the most effective way of achieving this would be to have teachers virtually meet in small groups where they could interact with each other and the established knowledge base, discussing what theory would be most appropriate to their given situations. They need to be given opportunities to construct plans, to try some strategies out in their virtual classrooms, reflect on those experiences and then come back to the group and critique what happened. The teachers should take their reflections, the criticisms and ideas of their colleagues, and make new plans that they can take back into their virtual classrooms for another cycle of action. This is, in short, action research. These were the processes in which the AQ course designers were engaged during this research project.

The research questions that the research team was interested in pursuing were:

1. How does the structure of social presence within the community adapt as a consequence of disruptions that are inherent in FOLC environments?
2. Posing the FOLC as a grand conjecture, can we elicit refutations to the model through the development process - bridging the theory to practice and investigating the nature of praxis within FOLC contexts? How does the act of implementing the FOLC create modifications to participants about the FOLC?
3. How do the elements within the FOLC design process facilitate or provide opportunities for cognitive growth and a pedagogical paradigm shift towards learner-centered, open-ended digital environments?
4. How has participant thought regarding the concept of FOLC readiness been modified through your involvement in the design and implementation of your AQ course?
5. How has the way participants define online communities and the associated roles and structures impacted the way you view AQ course design?

Methodology

The Fully Online Learning Community Model (FOLC) was shared with the AQ designers in conjunction with the Ontario College of Teachers (OCT) in a face to face half-day workshop on site at the OCT in Toronto, Canada. ,a series of 7 additional fully online workshops were made accessible to the AQ designers. The methodology of the project reported here was conducted as a 'purposeful action research' study following teams of instructional designers/teachers and OCT staffers as they undertook the design and implementation of Additional Qualification courses using the FOLC Model. By "purposeful action research" (vanOostveen, 2005), an intentional approach connecting teachers to external influences that can shape their process was adopted. Data sources included recordings from the series of audio/video conference workshop sessions, Knowledge Forum reflective posts and Slack messages, the results of the Digital Competency Profiler (DCP), a digital competency and usage toolset, at the beginning/end of the project, and a series of semi-structured interviews throughout the project. Knowledge Forum was used for it's affordances in support of participant metacognition, while Slack was used for general communication and file sharing. Participants voluntarily participated in all aspects of the project and as a consequence some of the components were much better attended to than others, resulting in a richer data set. The research team is in the process of analysing all of the data and then assembling the comprehensive views of the participants as they went through the process of assembling their AQ courses.

This article focuses solely on a preliminary partial analysis of the WebKF posts. Several researchers from the team read through all of the posts, following the threads. This amounted to a chronological reading of the posts. Good use was made of the Timemachine assessment tool. A thematic analysis was carried out (Glaser & Strauss, 1967), specifically to investigate any cross-correlational conversations between individuals within the community. The resulting themes are reported and discussed in the following section.

Results and Discussion

From the Knowledge Forum Activity Dashboard, there were 106 posts created, 250 modified posts and a total of 1353 reads. This activity was inclusive of posts added by the research team, by the 16 participants who volunteered to work in the WebKF environment. The majority of posts coincided with the workshops that were offered from April through to June 2019. There was another spike of activity occurring through July 2019.

In order to examine the full-learning experience of the participants, results will be subdivided into each of the modules in WebKF and presented in chronological order of when each module was released to the participants. At the end of each module discussion a quote is provided that exemplifies the findings on WebKF.

Welcome/Digital Competencies and Learning in FOLC Environments View

Participants suggested that they had some background in technology, although some mentioned the struggle using technology is still on-going. Most participants commented on the emotionality of using technology, both for themselves and how a facilitator in a digital environment must feel. Although they see the potential of FOLC, they seem to focus on the negatives of using technology (specifically in regards to technology failure). It should be noted specifically that the feelings participants were expressing seemed to be a reflection by participants of their own lack of confidence in using the technology for educational purposes, rather than a reflection of the actual usefulness of working within a co-constructed digital environment. Despite this dissonance between the benefits/detriments of using technology for educational purposes and their own personal feelings, they wanted to improve their own digital competencies and were excited by the possibilities that FOLC presented.

> As someone who is not digitally competent, my initial scan of the [technology] article reinforced my apprehension (e.g., print heavy, acronyms, assumption of technical terms, [an] assumption I would not understand). There was an emotional response rooted in my lack of confidence in this area. I pushed through this… I found myself connecting to the dimensions of learning that are possible in Knowledge Forum... This is what hooked me and helped me get past the technology requirements… (Participant 1, 3/26/2019, 3:29:13 PM)

Using Authentic Assessment in FOLC Environments View

In this module, participants discussing authentic assessment pointed out that different personal preferences for kind activities should be used for differing personalities of learners, and that FOLC could play to catering to these differing preferences. There was also discussion on assessment as learning (formative assessment), and how in the FOLC it should be used for demonstrating learning and showing the growth of the learner, and thereby providing support to the learner. Participants expressed disdain for achievement charts, and emphasised the importance of students using self-assessment and reflection, although there was no elaboration on how to do this necessarily in an actual classroom. Finally, there was some discussion on how to make authentic tasks authentic to learners, or to curriculum, which there was some relation back to self-reflection and the idea that one can't be authentic without self-reflection.

> … There has been mention of the importance of including students in the creation of both learning and assessment tasks; I believe they are one and the same. The process of reflection should be inherent in any task, and through that reflection, there should be the opportunity to demonstrate insight and learning in whatever form is uniquely available to the student… (Participant 2, 3/31/2019, 12:24:50 AM).

> … I know what I have learned and I think self-assessment is an authentic gauge of learning....more so than getting a grade. Opportunities for self-assessment are integral to authentic tasks and authentic assessment (Participant 3, 4/2/2019, 5:28:34 PM).

PBLO Use in FOLC Environments View

Participants described that the FOLC model seems to create co-inquiry opportunities between students and teachers when in class, meaning that both assume responsibility for learning. FOLC was mentioned as seeming to be a balancing act between freedom, responsibility and meaning gained from a course, and that the integration of PBL is a "total approach to education" by presenting real challenges to learners.

> … PBL is a total approach to education. And there is a PBL process, which, among other things, replicates the commonly used systematic approach to resolving problems or meeting challenges. Students assume the responsibility for learning and teachers become facilitators: stimulating and guiding students' in their problem solving and self-directed learning... (Participant 4, 4/8/2019, 2:51:16 PM).

Facilitation of Learning in FOLC Environments View

Participants here shared their thoughts on the role of facilitation on learning within the FOLC environment. The following are descriptors that participants used to describe what they felt that a facilitator in a FOLC would embody: powerful, influencer, co-inquirer, co-facilitator, critical pedagogue, comfortable with technology, curator, knowledge mobilizer. Most of the posts in this section described how a facilitator would be or act like, but again there were no practical implementation suggestions provided.

> An online facilitator in an FOLC AQ course: is comfortable with using technology and open to learning new tools as they are presented, plans for dissonance and expects periods of silence, doesn't settle for one voice, one point of view, asks questions when questions are asked, loves learning/inquiry and will engage others in exploration, is experienced in the practice of teaching, is passionate about the content/topic/subject, is caring and kind to others; is authentic, makes decisions based on the needs, interests of the collective and shares the decision making role with the collective, provides and promotes feedback and reflection, recognizes connections and enables others to make their own, believes in fully online learning (Participant 5, 4/9/2019, 5:57:35 PM).

Designing the Digital Environment View

In this module, none of the participants made any comment or post. Although there is no data to present, the lack of data and participation could be for several reasons. Based on previous comments from participants, the most likely reason is that the participants still treat technology as a means to an end, instead of an end in themselves. They most likely do not see technology as something as being a part of an environment, or an environment itself, but a concrete object that acts as a conduit for their teaching. As with some of the discussion with the first module *Welcome/Digital Competencies and Learning in FOLC Environments,* this could also be an indicator that the participants might not perceive the usefulness of working within a co-constructed digital environment.

Designing and Building your AQ Course View

For this final module, much of the discussion seems to have stemmed from two participants. In these conversations, participants were wanting to create a sense of belonging and a community of learning in AQ courses. However, participants expressed the possible tension between the community and freedom of the individual, and what this meant for their AQ courses. Finally, there was some discussion on making the instructor "invisible", in the sense that the role of the instructor should be one of a facilitator and that the learning community as a whole should have shared ownership of each other's learning. In the end, participants expressed more questions than in any other module which suggested that they wanted to learn more about FOLC and how to implement it in their own AQ courses.

> as an AQ facilitator and co-learner, how will I foster a sense of belonging to this community of learning? as a community of learning, how will we share responsibility and ownership? how will the collective identity of the community support freedom, shared power, flexibility and innovation? what processes and interactions will enable and sustain authentic relationships throughout the course? how do we come to know, trust and respect members of our learning community (Participant 5, 4/29/2019, 10:51:36 AM)?
>
> Are you aiming to be invisible as an instructor or that the role of the instructor is invisible because everyone in the learning community has shared ownership? Working with colleagues, I found taking that active learner stance alongside candidates was huge for a successful course… (Participant 6, 5/14/2019, 11:36:06 AM).

Conclusions

Interactions with project participants showed that their desire to transform their understanding of learning within fully online community contexts was in tension with their perception of the parameters for course revision, which were inconsistent with the underlying premise of the FOLC model. The authors and participants found that learning occurred not in spite of, but as a result of, socially constructed disruptive dialogue, reflection, and collaborative group processes. Further analysis will be carried out on the various data sources and further implications of this work will be reported in upcoming conferences and journal articles.

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On the Interplay of Social Presence, Idea Improvement and Knowledge Development in Knowledge Building Communities

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Abstract: The results of this research provide an account of advances in foundational knowledge of black-hole physics through analysis of idea improvement and social presence in Grade 12 Knowledge Building classes. The purpose of this study is to collect and analyze student discourse and interactions to uncover socio-cognitive dynamics in an online environment—Knowledge Forum®—designed to support Knowledge Building. Social interactions were quantified within discussion threads using social presence to identify affective, cohesive and interactive markers of engagement. According to expert judgment, students demonstrated impressive levels of understanding black-hole physics while applying Knowledge Building principles to their discourse. Additionally, all markers pointed to one group displaying especially high-levels of collective responsibility for community knowledge. Those results are consistent with the teacher's impression that a *Knowledge Building esprit de corp* characterized the most successful student group.

Introduction

Scardamalia (2002) has argued that knowledge advancement "is in the social fabric of the organization" (p. 8). This statement suggests that organizations such as Knowledge Building communities work best in advancing knowledge and ideas when members of the community attend to both cognitive and social interactions for advancement to occur. Social engagement is an important component for the success of a Knowledge Building activity as evident in the social requirements associated with the twelve principles for Knowledge Building (Scardamalia, 2002). Specific principles that rely on social interactions require students to (i) assume a collective responsibility to share knowledge so as to advance knowledge of the community (ii) practice epistemic agency where participants negotiate the integration of personal ideas and the ideas of others (iii) distributed expertise among the members of the community so that no single person is responsible for producing knowledge (iv) practice Knowledge Building discourse where knowledge is refined and shaped by the social interactions of the community. Specific words such as 'share', 'negotiate', 'distributed' all indicate that knowledge advancement requires productive social interactions if cognitive advances are to occur. Knowledge Building requires a co-occurrence of both social and cognitive components that work in concert to produce knowledge, create ideas and promote idea improvement among community members. This is the essence of collective socio-cognitive responsibility required for Knowledge Building to flourish where members of a community share in the overall advancement of knowledge and idea generation.

I (first author) have been using Knowledge Building as a constructivist learning environment in my classroom for over ten years, primarily in science and physics. The work presented here involves Knowledge Building communities in my grade 12 physics classrooms surrounding topics in modern physics specifically black hole science (no prior scientific knowledge on black hole science is required by the reader to understand the outcomes of this work). While reading the notes posted by my students on this topic, I noticed that my attention gravitated toward one community in particular. Their conversations not only seemed cognitively rich and coherent, but they also attended to each other socially in ways that the other communities under investigation lacked. This one particular community seemed to possess a group 'togetherness' or 'esprit de corps', with discourse seemingly more socially driven and personalized in relation to other communities under similar academic conditions.

A reasonable question is whether heightened social engagement during online discourse - or 'social presence' - imparts cognitive advantages to an online community as a result. Previous research reporting on the interplay between social presence and academic outcomes suggests that this may be the case (Picciano, 2002; Joksimovic et al. 2015). In the work presented here, we investigate whether social presence influences Knowledge Building discourse – specifically in tune with Knowledge Building principles - surrounding two identifiable outcomes found within the discourse threads in Knowledge Forum: knowledge development and idea improvement.

Examining Knowledge Building communities for social presence indicators can indicate the degree to which a community is socially interacting and may subsequently affect educational outcomes such as foundational knowledge development and idea improvement. We seek to answer two questions.

1. Is there evidence of socially supportive online discourse for Knowledge Building communities in courses I have taught? Does one group exceed others in markers of social presence?

2. Is there evidence of idea improvement and knowledge advancement in online discourse for Knowledge Building communities in courses I have taught? Does one group exceed others as measured by various indicators of idea improvement and foundational knowledge advancement?

What is Social Presence?

To examine the social processes surrounding Knowledge Building discourse in this work, I used the lens of social presence to clarify social interactions occurring within Knowledge Building communities in several of my grade 12 physics classes. Social presence was first suggested by Short, Williams, and Christie (1976) as a way to understand how an individual can present themselves as important to others during online discourse where facial expressions and body gestures are absent from view. Within online learning environments, Gunawardena and Zittle (1997) described social presence as "the degree to which a person is perceived as a 'real person' in mediated communication". Being a 'real person' within a computer-mediated community is dependent upon creating an impression or remembrance of oneself while interacting socially either synchronously or asynchronously (Kreijns, Kirschner, Jochems & Van Buuren, 2007). Furthermore, promoting a sense of realness is also dependent upon the style of communication used to project themselves as real (Rourke et al., 1999). Rourke sought to measure this projected realness by looking for social presence indicators found within posted messages that could then be quantified. Clear indicators within messages such as using names, greetings and compliments are viewed as evidence for social presence. Furthermore, members may use non-verbal social cues such as emoticons '☺' and/or expressions of emotion using '!!' that enhance their perception as 'real' people within the community.

Attempts to identify social presence has occurred using self-reporting surveys (Tu, 2002; Gunawardena and Zittle, 1997) and quantified using identifiable markers first described by Walther (1992) then expanded up by Rourke et al. (1999). Rourke conducted content analysis of transcripts to isolate three key categories of responses associated with social presence within an online community: affective, interactive and cohesive responses. Affective responses include those responses that express emotion, feelings and mood. Those would be characterized with the use emoticons, humour and self-disclosure. Interactive responses were identified when group participants were "attending" to others in the group in some identifiable way. Interactive responses saw participants referring to the work of others, quoting directly from others, complimenting and expressing appreciation. Finally, cohesive responses are those that appeared to support and maintain a sense of group togetherness. Table 1 outlines these three categories along with associated indicators within each category.

Table 1: Template for assessment of social presence markers (Rourke et al.,1999).

Category	Indicator	Definition	Example
Affective	Expressions of emotion	Conventional or unconventional expressions of emotion, includes repetitious punctuation, conspicuous capitalization, emoticons	This is cool!! HELLO! :) or :(
	Use of humour	Teasing, cajoling, irony, understatements, sarcasm	'Hey, let's throw Paul into a black hole and see what happens."

	Self-disclosure	Expresses vulnerability, or provides life details outside of classroom experience	"I'm not sure about my answer…" "I'm confused"
Interactive	Continuing a thread	Using the reply feature of software, rather than start a new thread	Software dependent
	Quoting from other's messages	Using software features to quote others entire message or part of a message	Copies and pastes a small section of a larger note
	Referring explicitly to other's messages	Direct references to contents of others' posts	"In your post, you referred to …."
	Asking questions	Students ask questions of other students or the moderator	"Do you think it works this way?"
	Complimenting, expressing appreciation, expressing agreement	Complimenting others or contents of others' messages Expressing agreement with others or content of others' messages	"Nice work everyone!" "That was my thinking exactly" or "I agree with Alex."
Cohesive	Vocatives	Addressing or referring to participants by name	"John mentioned something interesting."
	Addresses or refers to the group using inclusive pronouns	Addresses the group as *we, us, our*	"Our thinking is the same as the researchers."

Table 2 shows an example of how social presence markers were naturally used during Knowledge Building discourse in one of my grade 12 physics classes. In this exchange, we see evidence of affective, interactive, and cohesive indicators expressed throughout the conversation. We see the use of emotion ('!') by both S1 and S2 (notes 6 and 7) and the use of emoticons (':p') by S1 in note 5. We observe complimentary behaviour through appreciation (notes 6 and 8), expressing agreement (note 7), and asking questions to aid understanding (notes 2, 4 and 6). Finally, we see the use of inclusive pronouns (note 8, "*us*" and "*we*") and direct use of names (note 4).

Table 2: A series of notes highlighting examples of social presence indicators. Words in bold represent the scaffolds used in Knowledge Forum.

1. elaboration on neutron stars by S1
Elaboration Neutron stars form when a star with a mass greater than 4 to 8 times the size of our sun goes into supernova, and the result is a core of massively dense material. A neutron star is usually about 20km in diameter and has a mass 1.4 times that of our sun. On earth, a teaspoon of neutron star material would weigh about a billion tons. Neutron stars also have an extremely strong gravitational and magnetic field. Neutron stars are called as such because when the core of the star collapses under its own gravity, protons and electrons combine to make neutrons.

2. where are they now? by S2
I need to understand are these neutrons that are being created by the coming together of the leftover protons and electrons entering the black hole if one if being created or are they being spat back out into the universe for further use?

3. does this help? by S1
My Theory These neutrons are actually what help make up the neutron star. When a neutron star forms, no black hole is formed. The neutron star is made up of the really dense matter partly because of these newly made neutrons.

4. I think so! by S2
Opinion yes thanks [uses S1's name here]. **Evidence** so then in this picture [Figure not shown] the section where [it] says "many neutrons and other particles" is where these neutrons being formed would reside? or is this whole star itself what's being formed?

5. answer by S1
Putting our knowledge together Yes that would be where the neutrons and other particles reside. Keep in mind the neutrons are only formed at the time the neutron star is formed, not after :p

6. tomato analogy by S2
Opinion thanks so much! so the neutrons are formed during the formation of the neutron star so they are just created as a part of it. **Elaboration** kind of like how a tomato is formed with its seeds?

7. exactly! by S1
Opinion Exactly! I may use that analogy later on...

8. yay us! by S2
yay I'm glad we have reached a **Conclusion** - a neutron star is much like a tomato (formation wise of course!)

Examining for Indicators of Social Presence

Three groups of senior physics students - Group A (*N* = 7) Group B (*N* = 5) and Group C (*N* = 6) – were examined for their use of social presence indicators (see Table 1) during their knowledge building discourse in the area of black hole science. Content analysis was conducted on the notes by the first author and subsequent analysis of knowledge development and idea improvement was conducted by experts in the field of black hole science.

The total notes produced in Knowledge Forum by all three groups were analyzed for the ten indicators of social presence shown in Table 1 under the affective, interactive and cohesive categories. The total number of instances of social presence indicators for each category was counted and then divided by the total number of words produced by each group. This quantity is what Rourke (1999) refers to as a social presence "density" whereby the greater the density value the greater the social presence. Social presence density (SPD) is calculated using the following formula.

$$SPD = \frac{Total\ number\ of\ social\ presence\ indicators}{Total\ number\ of\ words} \times 1000$$

Table 3 shows the social presence category scores along with the social presence density score for each group. The numerical values represent the sum of all incidences/1000 words. The results show that the affective, interactive and cohesive categories were highest with Group B followed by Group C finally Group A. A one-way ANOVA ($p < 0.05$) was conducted upon three groups and determined statistically significant differences for social presence among the three groups [$F(2,6) = 10.23$, $p = 0.012$)]. Post hoc comparisons using the Tukey HSD test indicate significant differences between Groups B and C, and Groups B and A. No significant differences were found between Groups C and A.

Table 3: Social presence category scores and social presence density scores (incidences/1000 words).

Category	Group		
	A	B	C
Affective	0.36	7.09	1.31
Interactive	0.31	3.56	0.69
Cohesive	0.16	3.17	0.23
Social Presence Density	0.83	13.82	2.23

Next, a deeper analysis was conducted by comparing individual indicators under each category of social presence as outlined in Table 1. Figure 1 shows the three categories along with the individual indicators for each group. The indicators reported are quantified per 1000 words.

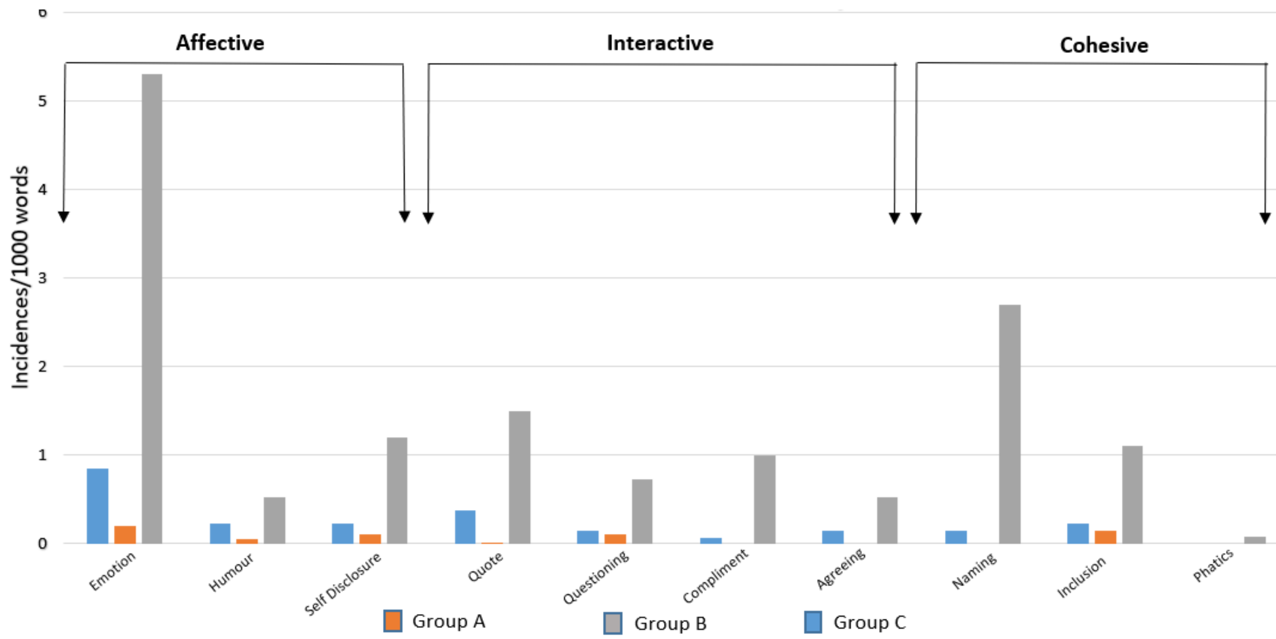

Figure 1. Comparison of individual social presence indicators among Groups A, B, and C.

A one-way ANOVA test ($p < 0.05$) was conduct on the individual indicators shown in Figure 1 under the three categories. The results of the ANOVA test indicate a statistically significant difference in social presence among the individual indicators for the three groups [$F(2,27) = 7.33$, $p = 0.003$]. Post hoc comparisons using the Tukey HSD test indicate significant differences between Groups B and C, and Groups B and A. No significant differences were found between Groups C and A.

Indicators for social presence was found within the discourse of all three groups. However, the data presented indicate a clear distinction between the three groups in terms of their social presence. The community members of Group B present the highest scores on all ten indicators of social presence while Group A showed the lowest. This leads us to ask whether having a comparatively higher social presence density score confers any advantage in terms of knowledge development and idea improvement.

Examining for Knowledge Development and Idea Improvement

Five experts in the field of cosmology volunteered their time to examine a packaged set of notes produced by each group on how black holes are created. Each expert has extensive experience, either through teaching and/or research, in black hole science. Four of the experts hold a Ph.D. in physics. The five experts were given identical sets of notes from each of the three groups to evaluate. The evaluation had the experts look at two areas of interest related to this study: (i) the depth of foundational knowledge developed and (ii) the depth of idea improvement observed. To evaluate the depth of foundational knowledge developed by each group, those experts used the following question to guide their evaluation, '*At the introductory level, how well did the group work to answer the question, 'How is a black hole created?''* The 'introductory level' statement is used to indicate to the experts that the students lacked prior knowledge in black hole science. To judge idea improvement, the experts were given the following statement to help them comprehend the concept: *When working with knowledge, all ideas are treated as improvable. Participants work continuously to improve the quality, coherence and usefulness of ideas presented. Participants recognize what is known and what needs to be known by requesting new information (*e.g., *through question-asking) or clarification on information already presented to the group resulting in conceptual advancement in understanding on the topic discussed.*

Expert evaluation of both knowledge development and idea improvement was conducted using a four-point Likert scale is shown in Tables 4 and 5. Table 4 summarizes the scoring results by each expert in foundational knowledge development showing the individual scores, the average score (*M*) and the standard deviation (*SD*). In answering the question, 'How is a black hole created?' the overall results demonstrated that the Group B produced the highest foundational knowledge score ($M = 1.80$, $SD = 0.51$) followed by the Group C ($M = 2.60$, $SD = 0.37$) and last Group A ($M = 2.90$, $SD = 0.66$). A one-way analysis of variance (ANOVA) was conducted on the foundational knowledge developed by the three groups. The results of the ANOVA ($p < 0.05$) indicate a statistically significant difference between the three groups [$F(2,12) = 4.6$, $p = 0.033$]. Post hoc comparisons using the Tukey HSD test indicate significant differences between Groups B and A. No significant differences were found between Groups C and A or Group C and B.

Table 4: Expert ratings for foundational knowledge development surrounding the question: 'How is a black hole created?' 1 = very complete, 2 = mostly complete, 3 = partially complete, 4 = incomplete.

	Group A	Group B	Group C
Expert A	2	2	2.5
Expert B	2.5	1.5	3
Expert C	3	2	2.5
Expert D	3	2.5	2
Expert E	4	1	3
Average	2.90 (*SD* 0.66)	1.80 (*SD* 0.51)	2.60 (*SD* 0.37)

Table 5 summarizes the scoring results for idea improvement among the three groups for the question, 'How is a black hole created?' Group B achieved the highest idea improvement score ($M = 1.85$, $SD = 0.89$) followed by the Group C ($M = 2.40$, $SD = 0.49$) and finally the Group A ($M = 4.30$, $SD = 0.40$). An ANOVA ($p < 0.05$) was conducted indicating a statistically significant difference between the groups [$F(2,12) = 16.6$, $p = 0.000$] surrounding idea improvement. Post hoc comparisons using the Tukey HSD test indicate significant differences between Groups A and B, and Groups A and C. No significant differences were found between Groups C and B.

Table 5: Expert rating results for idea improvement among Groups A, B and C. 1 = excellent, 2 = very good, 3= good, 4 = fair, 5 = poor.

	Group A	Group B	Group C
Expert A	4	2.5	3
Expert B	4	1	2
Expert C	4.5	1.5	2
Expert D	4	3.25	2
Expert E	5	1	3
Average	4.30 (SD 0.40)	1.85 (SD 0.89)	2.40 (SD 0.49)

Post evaluation interviews were conducted with all the experts to help clarify their scoring and to give feedback on the engagement of each group. For comparison purposes, I contrast the highest-level group B and lowest-level group A. With Group B, experts noted the interplay between foundational knowledge development and idea improvement, the highest scoring group surrounding social presence, knowledge development and idea improvement. Expert B noted the enhanced group dynamic while they tried to understand black hole formation.

> *"Their knowledge generation was primarily through idea improvement. There weren't individuals coming up with a separate chain and trying to progress in that fashion. People weren't presenting their own version of the entire story. People were positing questions…they would very clearly say each time there were things I need to know and I don't understand why this happens. And people would start to answer them. And it's in that answering that they would converge rapidly onto the right answers. They were apparently unafraid to say, 'I don't think that's how it is. I think it is like this'. I would call this excellent."*

Expert C offered this overall impression about Group B hinting at their higher degree of social interaction and esprit de corps as they worked together.

> *"I was more impressed with this group* [Group B] *I'd say, based on ideas and questions asked and then helping to develop and answer those questions. They just seemed more happy, more supportive…"*

Taken together, these experts recognized the advanced social interactions occurring with Group B and their advanced knowledge development and idea improvement co-occurring. Conversely, experts noted Group A did not have as heightened social interactions as that of Group B. Expert B was succinct in his evaluation of idea improvement for this Group A stating,

> *"There is no serious evidence of collaboration. There is not a lot of interaction. I would say it is a rather limited degree of idea improvement."*

Expert E appears to understand how the lack of social engagement within the group has limited Group A's ability to develop knowledge at a much deeper level in understanding black hole formation stating,

> *"I think they should have kept looking back at what their question was. There was nothing wrong on what they said. They did summarize stellar evolution quite nicely. They put down facts but then they really didn't ask themselves 'Ok, do I really understand this, why is it that more massive stars ultimately become black holes?' They tried to answer that a little bit but they certainly didn't go very deep. So part of that is having another group member say 'well ok, thanks for that. Let's go one step further and figure out why some stars go here versus here'. They could have helped each other go a bit deeper."*

Discussion

The first question of this study examined whether there was evidence of socially supportive online discourse among the three groups and whether one group exceeded others in markers of social presence. When the social presence density score was determined for each group, Group B expressed the highest social presence density score compared to the other two groups. Specifically, Group B had the highest expression in the affective, interactive and cohesive categories followed by Group C, then Group A with the lowest scores for all three categories. Conversely, Group A was lowest on all of these dimensions. The contrast in both cognitive and social discourse between Group A and B was identified independently by experts as elaborated in their recorded interviews and independent evaluation of the notes of each group. The experts identified more elements of social presence within the discourse of Group B without being cognizant of these associated indicators particularly those indicators within the interactive category.

The second question examined for idea improvement and knowledge advancement and whether one group exceeded others in these two important areas. When experts examined cognitive work surrounding knowledge development and idea improvement on black hole formation, Group B was unanimously rated as the highest performer for both knowledge development and idea improvement. Of note, the experts independently remarked upon the explanatory discourse of Group B as a primary contributor to their knowledge advancement. These experts noted the social engagement of Group B during the groups' discourse, especially how they helped each other either through question-asking and/or providing explanatory help to advance their cognitive goal of understanding black hole formation. Overall, it was impressive that students in all three groups - using Knowledge Building principles - were able to create and work with questions, knowledge, and ideas within their groups that expert evaluators felt were foundational to black hole formation, despite interesting differences in interactions surrounding idea improvement and knowledge development.

The combined results from the two questions in this study suggests that higher expression of social presence co-occurs with superior production of idea improvement and knowledge development and idea generation. This study indicates that to amplify the cognitive outcomes during Knowledge Building discourse, practitioners of Knowledge Building should attend to the importance that social interactions plays during online discourse, as social negotiations seem to play a significant role in achieving desired cognitive outcomes. Consider the Knowledge Building principle of improvable ideas. The successful execution of this principle within a Knowledge Building community relies on a culture of psychological safety where "people feel safe in taking risks – revealing ignorance, voicing half-baked notions, giving and receiving criticism" (Scardamalia, 2002, p. 9). Social presence seems a proxy for a form of thoughtful, empathetic response that engages participants in working harder—establishing a norm of idea improvement. Social presence in the context of this study opens an important line of future research to examine the interplay between the social and cognitive responsibilities and how they may amplify various Knowledge Building principles that may further enhance knowledge development and idea improvement.

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Collective Cognitive Responsibility in Knowledge Building Community: Theoretical Model Construction and Application Research

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Abstract: Through observation of Knowledge Building (KB) teaching practice in the secondary vocational schools, the researchers found that the big challenge for the teacher was many students pay more attention to specific skills operation and lack the ability and motivation of collaborative inquiry learning in the classroom. The guiding theory and effective strategies will be the bridge to the practice. This research initially constructs a theoretical model for the teacher to enhance the students' collective cognitive responsibility (CCR) in KB community. Under the guidance of the theoretical model, the corresponding teaching strategies are designed and is carried out in the first experimental class for a semester. The research team systematically analyzed the teaching practice data and revised the CCR theoretical model, then conducted teaching practice in the second experimental class for another semester. The results of data analysis from two teaching practices show that the CCR theoretical model is effective to enhance students' CCR.

Introduction

Knowledge-Building (KB) is a theory of teaching and learning facing the knowledge societies in the 21st century which has been an important research branch of International Learning Science. The goal of KB is to reframe school as a knowledge-creating enterprise (Scardamalia & Bereiter, 2003) and engage every student as a participant in the creation of knowledge, not just a receiver, sharer, or disseminator. At the same time, nobody should be excluded from knowledge societies, where knowledge is a public good, available to each individual. Everyone in the knowledge creating organization has the responsibility and obligation to contribute to the collective production of new knowledge, which requires that they to assume Collective Cognitive Responsibility (CCR) in order to truly promote the development of collective cognition and generate new knowledge.

A number of scholars have done relevant research on this topic. In a systematic analysis of 875 studies the Johnson brothers found that positive interdependence among group members was the key to improving group creativity (Johnson & R. Johnson, 1989; Johnson & R. Johnson, 1994). More recent work found that students working on electronic portfolios guided by KB principles showed deeper inquiry and more conceptual understanding than their counterparts (Lee & Chan, 2006; van Aalst & Chan, 2007). The distributed social structures in real-world knowledge creating organizations and resulted in the highest level of collective cognitive responsibility, knowledge advancement, and dynamic diffusion of information (Zhang, 2009). Some scholars believed that the more balanced distribution of impactful builders in each inquiry group can influence and enhance the cognitive process of other learners and promote their CCR and create more community knowledge (Braojos, 2015, 2019). There are also other scholars believe that that collaborative innovation networks (COINS) mechanism should be adopted to promote learners to undertake collective cognitive responsibility more effectively (Ma, Matsuzawa, Chen, et al., 2016; Ma, Tan, Teo & Kamsan, 2017).

The above research results are suggestive but lack in-depth theoretical analysis of the internal mechanism of CCR and of the efficacy of the teaching strategies intended to develop it. Relevant unanswered questions include: How can the processes by which community members develop CCR be effectively analyzed? How can effective teaching strategies be designed to promote development of CCR by a Knowledge Building Community (KBC)? To address these questions, this study carried out two semesters of teaching practice in two experimental knowledge building classes in secondary vocational schools.

Method and Process

In order to address these two research questions, we carried out teaching practice for two semesters in two experimental classes according to the design research process shown in Figure 1.

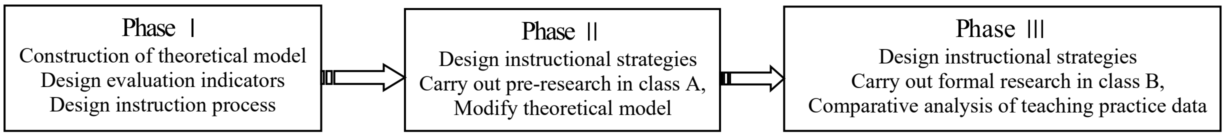


Figure 1. Research Process

Knowledge Building Environment

This study is a 2-year Design-based Research experiment (Collins, Joseph, & Bielaczyc, 2004) aimed at evaluating the possibility and means by which secondary vocational school students can assume collective responsibility for sustained knowledge advancement. Students reference, evaluate, build on, and work to continually improve ideas—their own and those of community members on the Knowledge Forum (KF) platform, which can provide statistics on the frequency of learners' participation and the number of posted notes and establish the social network structure among the Note-Linking.

Construction of CCR Model

Responsibility is a core concept in ethics, political science and law, and has multiple meanings. As used in these studies, the responsibility connects the ***subject, behavior, consequence and evaluation*** (Jonas, 1985; Wang, 2015). CCR is a kind of responsibility and it also involves three elements: subject, behavior and consequence. There are some differences in educational research, the consequence often refers to the result and effect of learning, and its essence is reflected in the development and change of learners' cognition, the evaluation reflects the result of CCR undertaken by learners, which is carried out separately in this study. According to the literature review and previous teaching practices, the paper analyzed the development and transformation process of the CCR assumed by the members in the KBC from the perspectives of the subject, cognition and process, and designed a three-dimensional theoretical model (Figure 1) for analyzing the KBC members' CCR for the pre-research providing a theoretical framework. In the subjective dimension, the role of the student who takes CCR is a dynamic process from individual to Knowledge Construction Group to class community, and the key influencing factor is the socialization structure of students. In the cognitive dimension, students' CCR is embodied in the gradual process from surface cognition to deep cognition, and the key influencing factor is the quality of KB Discourse. In the process of dimension, learners undertake CCR through the development process from no-discipline to heteronomy to self-discipline, and the key influencing factor is the establishment of KB rules.

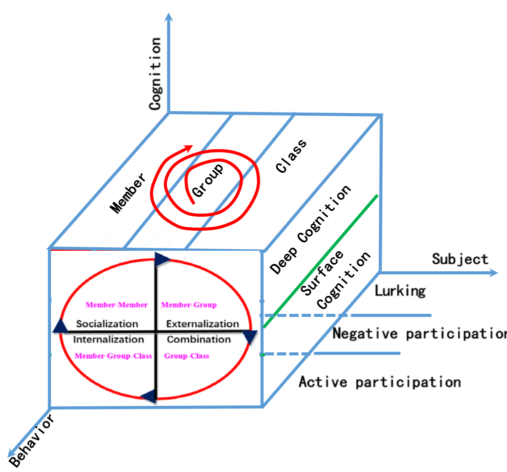


Figure 2. Initial CCR Model

Design Evaluation Indicators

The performance of learners' CCR is reflected mainly in three dimensions: behavior, cognition and subject, the research team constructed the evaluation indicators based on these dimensions.

Behavioral Dimension

There are many indicators to evaluate learners' participation. In addition to the indicators such as Frequency of Participation and Interaction Frequency on the KF platform, the research team has also constructed the member activity index (MAI) for assessing community members' CCR referring to Activity Index formula (1) which is a widely used index to evaluate the relative competitive advantage in the field of economics (J.D. Frame, 1977). The Activity Index formula is used to measure the competitiveness of a country, which is carried out by measuring the number of scientific papers published by various industries in a country, and it is very similar to the number of notes posted by learners in KF platform.

$$MAI= \frac{NMF/NMC}{NAMF/NAMC} \quad (1)$$

In MAI *NMF* denotes the number of notes posted by member A in Field K (The teacher and students divide the questions and notes posted by all the community members on KF platform into different research directions, Field K is one of them), *NMC* denotes the number of notes posted by member A in Community, *NAMF* denotes the number of notes posted by all members in Field K, *NAMC* denotes the number of notes posted by all members in KBC.

Cognitive Dimension

The common methods of evaluating members' CCR by researchers is online discourse analysis which identifies the epistemic levels of students' inquiry and explanation. (Eddy Y.C. Lee, Carol K.K. Chan & Jan van Aalst, 2006). However, there are also some ideas are declarative descriptions shown in Figure 3, not questions or answering questions. Following Piaget's theory of Genetic Epistemology, the author constructed a cognitive depth model (see Figure 4) referring to Biggs' SOLO (Structure of Observed Learning Outcomes, 1982) model and Webb's (2002) Depth of Knowledge (DOK) model for assessing these declarative descriptions. The author developed a rating scale for students' views which include questions, explanations and descriptive descriptions (see Table 1).

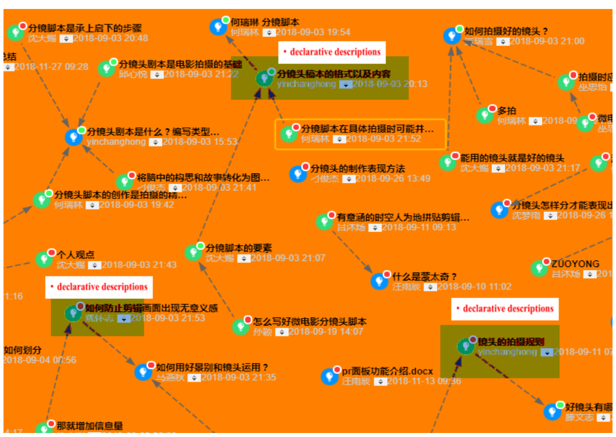


Figure 3. Declarative Description in KF Platform

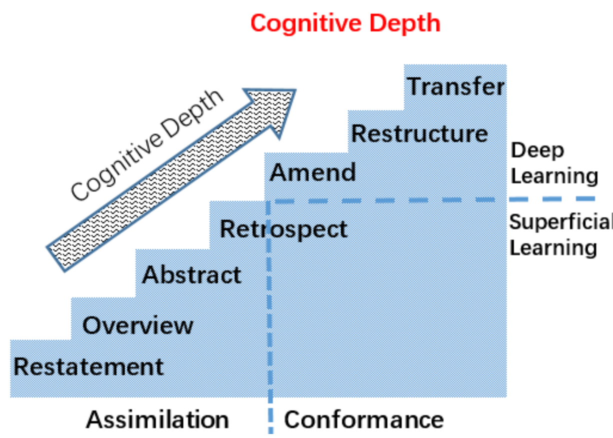


Figure 4. Cognitive Depth Model

Table 1: Rating scheme for cognitive depth

Rating	Description	Content Explanation
1	Restatement	Give opinion without evidence or elaboration; repeat or simply restate a fact or a statement that has been made, cutting and pasting are used rather than making their own interpretation.
2	Overview	Give factual information and general description; give a brief summary; responses are usually centered on facts and topics.
3	Abstract	Make a summary of the problem and different ideas, make a reasoning based on relevant information.
4	Retrospect	Make assertions supported with explanation, evidence and relevant examples.
5	Amend	Adjust and correct one's ideas and concept according to others ideas.
6	Restructure	Synthesize different points of views and make a 'rise-above' summary.
7	Transfer	Analyze problems in depth, explain problems from a theoretical level, and propose the solutions to the other related problems.

Community knowledge is public knowledge—ideas made accessible to all community members through contributions to collective knowledge spaces. Key terms (or words) represent a fairly objective unit of analysis and it is possible to easily extract key terms from a KF database as all the network behavioral data of KF students are recorded and stored. Some researchers used the Key terms to assess the Community knowledge in a knowledge building environment (Hong, 2014). Other scholars constructed the indicators of Key-term-based to measure knowledge elaboration (Zheng, 2016). However, because these indicators can't comprehensively reflect the quality of community knowledge, the author constructed a set of triangular evaluation methods based on key terms shown in Figure 5.

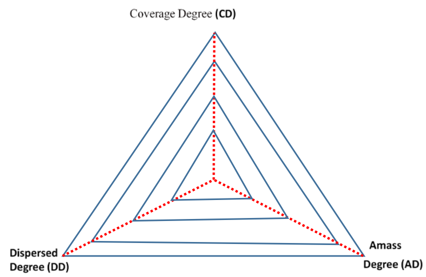


Figure 5. Triangular Evaluation

Coverage Degree indicator represents the scope of community knowledge covering teaching content and it can be calculated by formula (2). The larger the value, the wider the coverage of community knowledge.

$$CD = \frac{GKn}{EKn} \quad (2)$$

Where *GKn* denotes the total number of key terms proposed by all community members, *EKn* denotes the number of discipline keywords set by subject experts and professional teachers.

Amass Degree indicator represents the aggregation degree of community knowledge and it can be calculated by formula (3). The smaller the value is, the more diverse the notes are.

$$AD = \frac{Gkn}{\sum_{i-1}^{N} GiKn} \quad (3)$$

Where *GiKn* denotes the number of key terms contained in a member's notes and N is the number of community members. The same key terms may be contained in the notes posted by different members, the more key terms repeated, the more relevant the ideas discussed by students.

Dispersed Degree indicator (coefficient of variation which is the ratio of standard deviation to average) denotes the dispersion degree of community knowledge and it can be calculated by formula (4). The smaller the value, the more obvious the concentration trend of the views expressed by members, that is, the more balanced the community members' CCR.

$$DD = \frac{\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(GiKn - \frac{GKn}{N}\right)^2}}{GKn/N} \quad (4)$$

Instructional Design

The public discussion "Is one of the central ways that a learning community expands its knowledge" (Bielaczyc, 1999). In this study, the researcher designed and adjusted the content of the course according to the teaching plan; the instructional design is shown in Figure 6.

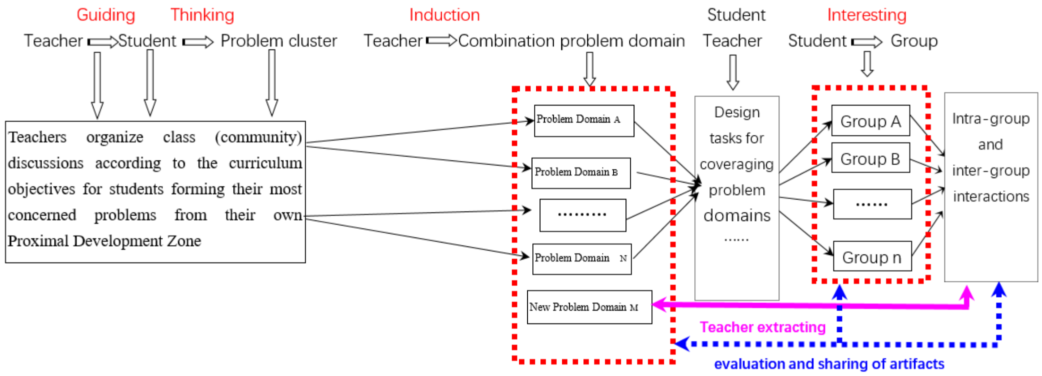


Figure 6. Instructional Design

The Process of Pre-research

The research team carried out the teaching practice in class A (9 Boys, 22 Girls) for 20 weeks in the fall semester of 2018 for a total number of 110 lessons. At the end of the semester, the students had posted 938 notes on the KF platform and formed seven television crews (see Figure 16). The teacher used four main instructional strategies including "jigsaw" method, KB Wall, Paper Task (Scaffold) and Class Report shown in Table 2.

Table 2: The instructional strategies in class A

Week	Course Content	Instructional Design
1-6 weeks Knowledge inquiry	Basic knowledge of video editing and clipping	**Jigsaw**—— Learners choose what to inquiry according to their interests
7-13 weeks Knowledge Building Intra-group Theoretical construction	Theory construction of video clipping Script, storyboard, shooting schedule	**Jigsaw**—— Learners with different knowledge backgrounds form inquiry groups **KB Wall**——Inter group interaction for only a week; **Paper task list**——Improve discourse quality
14-20 weeks Knowledge Building Inter-group Carry out practice	Video shooting Video clipping	**Practical training**——Video shooting and clipping **Class Report**——Each group will report the final video

The Process of Formal Research

After the pre-research finished, the research team systematically analyzed the experimental data, and interviews with students about the KB teaching, then modified the CCR model shown in Figure 7.

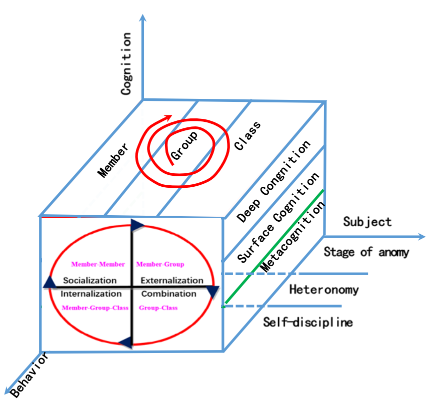


Figure 7. Modified CCR Model

The formal research was carried out in class B (13 Boys, 18 Girls) according to the modified CCR Model. The new instructional strategies such as KB circle, rotating group leader and participatory evaluation were used. At the same time, the instructional strategies such as KB Wall and electronic scaffold were adjusted. Those instructional strategies been used in Class B were shown in Table 3.

Table 3: Instructional strategies in class B

Week	Course Content	Instructional Design
1-4 weeks Knowledge inquiry	Basic knowledge of video editing and clipping	**Jigsaw**—— Learners choose what to inquiry according to their interests **KB Circle**—— Develop and enhance KB metacognition，foster knowledge construction culture ***Electric Scaffold***—— Structured KB discourse
5-9 weeks Knowledge Building Intra-group Theoretical construction	Theory construction of video clipping Script, storyboard，shooting schedule	**Jigsaw**—— Learners with different knowledge backgrounds form inquiry groups **KB Wall**——Inter-group interaction for 3 weeks ***Participatory peer evaluation*** ——Improve discourse quality and enhance interaction engagement
10-14 weeks， Knowledge Building Inter group Carry out practice	Video shooting Video clipping	***Rotating Group leader***——Rotating leader of the group should not only be responsible for the communication within the group, but also organize other groups to communicate in the classroom **Practical training**——Video shooting and clipping

The research team carried out the KB teaching in class B for 14 weeks in the fall semester of 2019 for a total number of 112 lessons. At the end of the semester, the students put forward 1465 notes on the platform of KF and formed six television crews (see Figure 17).

Data Analysis

The Data Analysis of Pre-research

The research team who carried out the instruction had taught with KB in school education for several years, and the teachers and administrators of the experimental school are very supportive of this educational reform. At the beginning of KB, the classroom atmosphere and the students' activities of mutual inquiry were very positive, but as the course drew on, the active classroom and mutual inquiry of the first few weeks corresponded with less activity in the KF database (Figure 8).

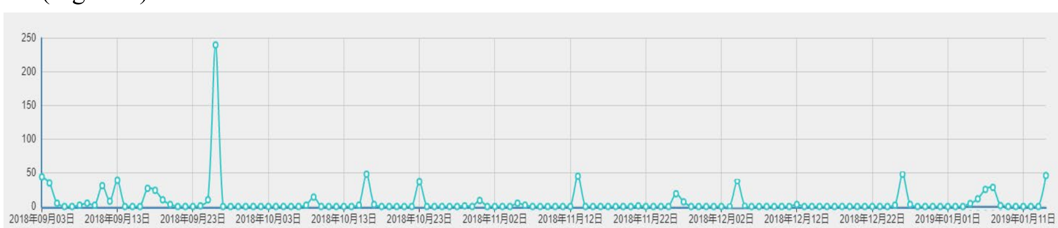


Figure 8. Frequency of Participation

In order to further investigate the above phenomenon, the researchers analyzed the change of learners' cognitive depth in the three stages and coded students' notes (Table 4).

Table 4: Coding of cognitive depth

Student ID	Date	Title	Ideas	Cognitive Depth
12	September 26	Script evaluation	I see a lot of psychological state in the script of *Come On Mengxi*. The script is different from the novel. The script language needs to be expressed by dialogues, voiceover, and body languages. The psychological state appears in the script. There is also a little use of punctuation in the script, the script is for actors, directors to see, improper use of punctuation will make people unable to understand, or do not understand, but read more laboriously. The above is for reference only.	4
18	September 3	Screenwriter	Screenwriters are mainly responsible for the plot of a movie and the actor's lines. In addition to these, they can also recommend actors to directors or give advice to actors according to the needs of their own plots. Writers are the creators of scripts and literary writings. They mainly complete the overall design of programs in the form of written expressions. They can either create original stories or adapt existing stories. Generally, after a good script is created, the script will be submitted to the director for examination. If it fails to pass the examination, the script will be re-created together with the director.	2
14	September 26	Storyboard	A storyboard is the concrete implementation of the director's ideas, which can be well represented by drawing or writing.	3
29	September 26	Script language	The language of the script includes two aspects: dialogues and stage directions. The dialogues are what the actor says in the play, including dialogues, monologues and narration. The dialogue in this play are few and incomplete, monologues and narration are not very specific.	3
10	September 26	The soul of clipping	Digital media is the use of visual information, the so-called soul is the author's ideas and creativity. Montage is just a technique. This technique is the experience of generations of editors. Only by expressing your creativity skillfully can you create soul-like editing.	2

All students' notes were scored by the author according to the rating scheme for cognitive depth; a second rater independently scored 30% of the sample. The Pearson Correlation for inter-rater reliability of cognitive depth was .86. The cognitive depth of students' ideas in the three teaching stages tested by independent sample test were shown in Table 5 and the cognitive depth of each student's idea been added up was shown in Figure 9.

Table 5: Independent samples test

Congnition Depth		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
1-6 Weeks 7-13 Weeks	Equal variances assumed	3.361	.072	-3.490	60	.001	-27.19355	7.79286	-42.78158	-11.60551
	Equal variances not assumed			-3.490	54.473	.001	-27.19355	7.79286	-42.81418	-11.57292
7-13 Weeks 14-20 Weeks	Equal variances assumed	12.648	.001	-5.581	60	.000	-39.03226	6.99395	-53.02224	-25.04228
	Equal variances not assumed			-5.581	42.683	.000	-39.03226	6.99395	-53.13993	-24.92459

The Sig. value in Table 5 were 0.001 and 0.000, both less than 0.05, indicating that the cognitive depth of learners was significantly improved in the second stage, and significantly decreased in the third stage. The results of the above data analysis show that the instructional strategies designed according to the CCR model only played a good role in the first stage, the phenomenon of KB inhibition and KB loafing appeared after the second stage.

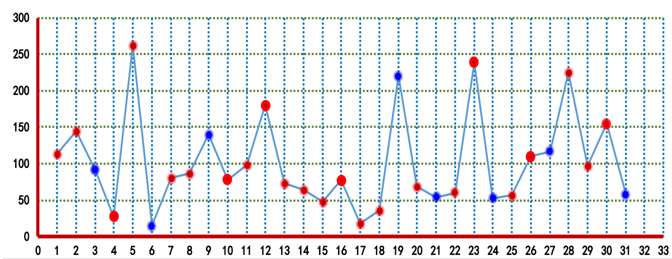


Figure 9. Distribution Curve of Cognitive Depth

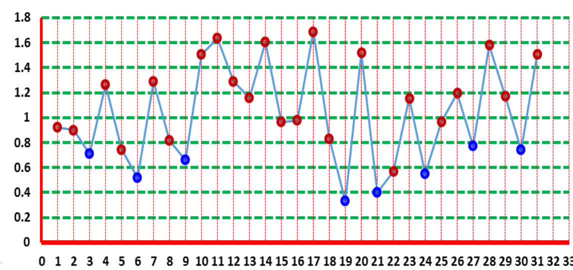


Figure 10. Distribution Curve of Average Active Index

When the individual performance of learners in a group are not accurately evaluated, they may become negative participants, which will lead to the case of KB loafing. Unclear tasks of individual members in the process of learning inquiry with no corresponding reward or evaluation can lead to a perceived gap between their abilities and expectations. As a result, they may not want to assume CCR, leading to the case of KB inhibition. The Distribution Curve of Average Active Index (see Figure 10) and Distribution Curve of Cognitive Depth (see Figure 9) fully explain the above two situations.

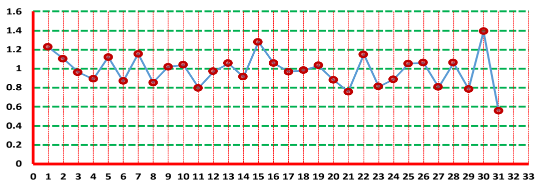
KB is still a relatively new educational theory in school education environment in China. Most students are unfamiliar with KB; they have some deficiencies in how to learn with KB principles and how to assume CCR. On the other hand, it is difficult to form the KB culture without the KB principles. Rules are the core of forming norms and group norm is an effective way to avoid inhibition and loafing (Daniel, 2017).As we know that the principle is a rule or belief that influences one's behavior and which is based on what he thinks is right (see the semantic meaning of principle in Oxford Dictionary), and principles are more guidelines than rules. In view of the above reasons, the author modified the three behavior types in the behavior dimension and added the meta-cognition on cognition dimension by adjusting the CCR model structure as shown in Figure 7.

The Data Analysis of Formal Research

The instructional strategies of Rotation Group Leader and Participator Peer Evaluation are very effective for cultivating the KB culture. The participation frequency of students has been effectively maintained (see Figure 11) and the average activity index of students is more balanced (see Figure 12) in the dimension of behavior.

Figure 11. Frequency of Participation

Although there are also some gaps in the different students' cognition depth (see Figure 13), the trend of these differences has slowed down compared with the pre-research (see Figure 9).



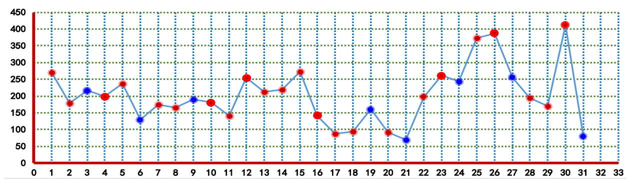


Figure 12. Distribution Curve of Average Active Index Figure 13. Distribution Curve of Cognitive Depth

Results and Discussion

Under the mechanism of Rotation Group Leader, each student has the obligation to organize the interaction within the group, and also has the responsibility to organize the interaction between groups. The mechanism in formal research is more conducive to produce group pressure, which makes most students actively participate in knowledge inquiry in the KB teaching.

The Cognitive Depth of Individuals Has Changed Significantly

The author coded all the students' notes according to the coding rules in the pre-research (see Table 4), and inputted the encoded data into SPSS, then made a comprehensive multiple comparative analysis of three stages about cognition depth of all the students' ideas as shown in Table 6.

Table 6: Multiple comparisons

Dependent Variable: Congnition Depth

	(I) Research Type	(J) Weeks	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane's	Formal (1-4weeks)	Formal (5-9weeks)	-40.83871*	7.91415	.000	-56.4551	-25.2223
		Formal (10-14weeks)	-26.09677*	7.91415	.001	-41.7132	-10.4803
		Pre-research(1-6weeks)	16.74194*	7.91415	.036	1.1255	32.3584
		Pre-research(7-13weeks)	**-10.45161**	**7.91415**	*.188*	**-26.0681**	**5.1648**
		Pre-research(14-20weeks)	28.58065*	7.91415	.000	12.9642	44.1971
	Formal (5-9weeks)	Formal (1-4weeks)	40.83871*	7.91415	.000	25.2223	56.4551
		Formal (10-14weeks)	**14.74194**	**7.91415**	*.064*	**-.8745**	**30.3584**
		Pre-research(1-6weeks)	57.58065*	7.91415	.000	41.9642	73.1971
		Pre-research(7-13weeks)	30.38710*	7.91415	.000	14.7707	46.0035
		Pre-research(14-20weeks)	69.41935*	7.91415	.000	53.8029	85.0358
	Formal (10-14weeks)	Formal (1-4weeks)	26.09677*	7.91415	.001	10.4803	41.7132
		Formal (5-9weeks)	**-14.74194**	**7.91415**	*.064*	**-30.3584**	**.8745**
		Pre-research(1-6weeks)	42.83871*	7.91415	.000	27.2223	58.4551
		Pre-research(7-13weeks)	15.64516*	7.91415	.049	.0287	31.2616
		Pre-research(14-20weeks)	54.67742*	7.91415	.000	39.0610	70.2939
	Pre-research (1-6weeks)	Formal (1-4weeks)	-16.74194*	7.91415	.036	-32.3584	-1.1255
		Formal (5-9weeks)	-57.58065*	7.91415	.000	-73.1971	-41.9642
		Formal (10-14weeks)	-42.83871*	7.91415	.000	-58.4551	-27.2223
		Pre-research(7-13weeks)	-27.19355*	7.91415	.001	-42.8100	-11.5771
		Pre-research(14-20weeks)	**11.83871**	**7.91415**	*.136*	**-3.7777**	**27.4551**
	Pre-research (7-13weeks)	**Formal (1-4weeks)**	**10.45161**	**7.91415**	*.188*	**-5.1648**	**26.0681**
		Formal (5-9weeks)	-30.38710*	7.91415	.000	-46.0035	-14.7707
		Formal (10-14weeks)	-15.64516*	7.91415	.049	-31.2616	-.0287
		Pre-research(1-6weeks)	27.19355*	7.91415	.001	11.5771	42.8100
		Pre-research(14-20weeks)	39.03226*	7.91415	.000	23.4158	54.6487
	Pre-research (14-20weeks)	Formal (1-4weeks)	-28.58065*	7.91415	.000	-44.1971	-12.9642
		Formal (5-9weeks)	-69.41935*	7.91415	.000	-85.0358	-53.8029
		Formal (10-14weeks)	-54.67742*	7.91415	.000	-70.2939	-39.0610
		Pre-research(1-6weeks)	**-11.83871**	**7.91415**	*.136*	**-27.4551**	**3.7777**
		Pre-research(7-13weeks)	-39.03226*	7.91415	.000	-54.6487	-23.4158

*. The mean difference is significant at the 0.05 level.

We can find that the cognitive depth of students' ideas in the formal research of class B has been effectively improved, and the indolence and inhibition was been avoided at the late stage of KB teaching in class B. For example, the Sig. value which is 0.064>0.05 between formal research (1-4 weeks) and pre-research (7-13 weeks) shows the cognition depth of students' ideas was increased much faster, the Sig. value which is 0.136>0.05 between formal research (5-9 weeks) and formal research (10-13 weeks) shows the cognition depth of ideas was well maintained.

The Interaction between the Members and Groups Was Significantly Improved

The social network analysis tools provided by the KF platform itself were used to analyze the notes of each member posted. Network density is an important indicator to measure and evaluate trend of social relations. The frequency of notes reading/being read in KF indicates the probability of community knowledge generation. For the same size of a social network, the higher the network density, the closer the relationship among nodes. It can be seen in the network structure that the members' interaction in Pre-research is more frequent and balanced than that in formal research (see Figure 14 and Figure 15).

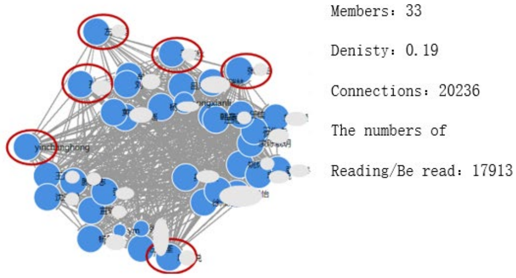


Figure 14. Pre-research

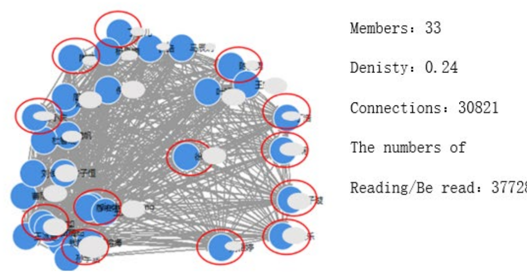


Figure 15. Formal Research

The social network among members cannot be comprehensively reflected the interaction between groups; it is necessary to conduct statistics manually and input the interaction data into the social network analysis tool to evaluate the interaction between groups. In some cases, the more frequent the interaction between groups, the more diverse views are. It can be seen from the network structure that the interaction among groups is more frequent and balanced (see Figure 16 and Figure 17).

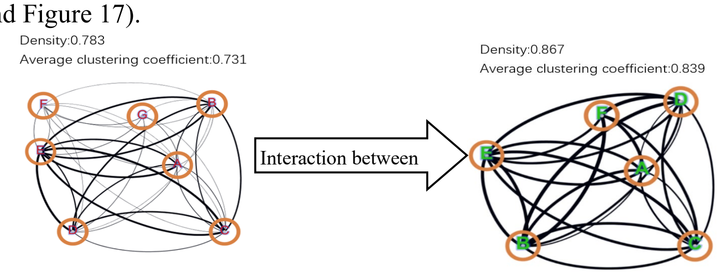


Figure 16. Pre-research Figure 17. Formal Research

The Community Knowledge Has Been Improved

In addition to the increase of individual cognitive depth and inter group interaction, community knowledge has also been improved. By comparing the triangular evaluation map between the pre-research and formal research, it can be founded that the community knowledge has been improved. The coverage degree, amass degree and dispersed degree of community knowledge were shown in Figure 18.

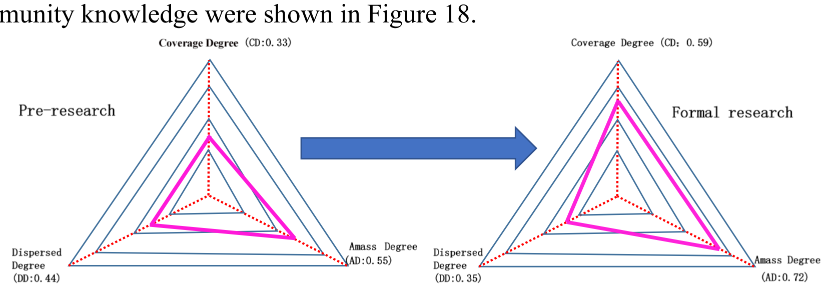


Figure 18. Community Knowledge

From the above data analysis, it can be concluded that the instructional strategies effectively improve the members' CCR. At the same time, these instructional strategies were designed and modified by the author according to the CCR model. Therefore, to a certain extent, it can be said that the CCR model is effective to improve students' CCR in KB teaching.

This study only evaluates students' CCR in behavioral dimension and cognitive dimension, and lacks subject dimension. At the same time, only two semesters of KB teaching practice have been carried out in this paper. In order to test the validity of the evaluation model and methods, the three-dimension model of CCR assessment should be carried out in more KB teaching in different schools and cities.

Conclusion

The paper draws two conclusions after two semesters of KB teaching. Firstly, the three-dimensional theoretical model of CCR is effective and it explains the internal mechanism of learners assuming CCR, and clarifies key factors that affect the community members taking CCR. Secondly, the teaching intervention strategies which were proposed by the research based on the key influence factor effectively promote learners to take CCR.

Next Steps

The researcher will use the word segmentation tools to segment students' ideas in each problem domain, and build knowledge map of views for measuring the members' CCR in the corresponding problem domain in the future research. On the other hand, how to construct an assessment method of evaluation KB culture will be the focus of follow-up research.

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Short Papers

Embedding Computational and Other Specialized Thinking in Knowledge Building

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Abstract: "Computational thinking," as it is currently being promoted, includes not only craft knowledge of software coding but also a kind of thinking developed by computer programmers that is believed to have more general value in many kinds of design and problem solving tasks. Virtually every discipline and skilled occupation has also been credited with distinctive ways of thinking worth learning for more general purposes. "Thinking like a lawyer," for instance, is an explicit learning objective in many law schools but may also have more general application in moral reasoning—not as a preemptive model but as an additional tool. This paper examines "thinking like" various kinds of specialists as an educational objective in terms of the close association between specialist thinking and substantive knowledge and the problems of extracting generalizable knowledge and skills from activities that highlight the exercise of craft skills. Embedding craft skills and "thinking like" a specialist within a larger Knowledge Building framework is proposed as a way of keeping larger objectives alive while obtaining the motivational and skill-learning value of concrete productive activity.

Introduction

Although developing knowledge and skills related to digital media has been an educational objective since the advent of personal computers and appears on every list of 21st century skills, the emergence of computational thinking as an educational objective (Denning & Tedre, 2019) represents a "rise above" the familiar goals. It aims at both a higher level of craft skills (ability to design and code software rather than only use it) and a higher level of cognition (internalizing the kind of thinking programmers do and applying it to design thinking and problem solving more generally). Computational thinking thus becomes something that should not only have a role in Knowledge Building but something Knowledge Building should be about—in the same sense that Knowledge Building is about ecology, evolution, complexity, knowledge creation, human rights, and other topics worthy of study.

Thinking like a programmer is said to differ from ordinary thinking in its emphasis on breaking a complex problem down into smaller parts that can be addressed separately. It is also said to involve thinking of problems in a way that a computer can help solve them. The two are quite different. The first is a heuristic, a strategic move that may or may not be helpful with a particular problem. A heuristic may be thought of as a conceptual tool that can be added to a person's thinking resources without any fundamental change to the person's other resources or way of thinking. Thinking of ways that computation could help in achieving some elusive objective, however, is neither a conceptual tool nor a skill. It is a design task calling for some level of invention and/or some new insight. It is, thus, a Knowledge Building/knowledge creation challenge. It means becoming, at least in some situations, a different kind of thinker.

Thinking like a programmer belongs to a fairly large and unorganized problem space that may be called "thinking like a specialist." If you enter the phrase "learning to think like" into a web search engine along with the name of some discipline or occupation you will discover discussions about the nature and value of "thinking like" in an impressive variety of fields. All the major academic disciplines will be represented, along with learned professions such as law and medicine. But "thinking like" applies to less conspicuously intellectual fields. In order to become more alert to dangers on the street, we are encouraged to "think like a cop." To safeguard our home against theft we are encouraged to "think like a burglar." There is also thinking like the practitioner of a particular trade or craft: e.g., thinking like a mechanic (Downtown Autobody, 2013) or like a weaver (Seitemaa-Hakarainen, Viilo, & Hakkarainen, 2010).

The idea running through all these discussions is that practitioners in a demanding field develop specialized knowledge skills attuned to the nature of their work but potentially of benefit outside it. Deliberate efforts to teach these specialized kinds of thinking are rare, however. Law is the most notable exception. Learning to think like a lawyer appears to be an objective that runs through entire law degree programs. In *Thinking Like a Lawyer: A New Introduction to Legal Reasoning,* Schauer *(2009)* discusses such distinctive characteristics of legal reasoning as the weight given to rules and precedents. He is clear that this does not always lead to the fairest judgements in particular cases, that the law is more concerned with fairness over a wide range of cases. However, this wider view of fairness could well have a place alongside reasoning from general moral principles, case-based reasoning, and reasoning by analogy in any sort of knowledge building dealing with human policy issues.

Exploring Signature Pedagogies: Approaches to Teaching Disciplinary Habits of Mind (Gurung, Chick, & Haynie, 2009) has chapters on teaching discipline-specific thinking in all the major subjects at the post-secondary level. At the school level, the only serious effort appears to be thinking like a historian: e.g., the "Reading Like a Historian" program (https://sheg.stanford.edu/history-lessons). In contrast, the typical school approach to teaching "scientific method" appears designed to teach students *not* to think like a creative scientist (Kirschner, 1992). School mathematics, with its emphasis on executing algorithms and solving specific assigned problems, gives little inkling that there is such a thing as mathematical thinking, an exception being work that engages students in discovering patterns and formulating rules to describe them (Moss & Beatty, 2006). Literature courses could be greatly enhanced by getting students to "think like a literary critic"—which is not the same as having an opinion about a literary work and defending it but involves going more deeply inside the work.

The Role of Substantive Knowledge in "Thinking Like"

Thinking skills approaches, such as those going by the name of "21st century skills" (Binkley, Erstadt, et al., 2012), typically focus entirely on process. Substantive knowledge is treated as something on a different dimension (Anderson & Krathwohl, 2001), something for thinking skills to act upon. However, in thinking like a programmer, a zoologist, a weaver, or other of the many specialized kinds of thinking, substantive knowledge of the domain is inseparable from thinking processes. This is evident in what is perhaps the most highly developed set of heuristics for thinking like a specialist, TRIZ (Orloff, 2013). TRIZ consists of 40 principles for producing inventive solutions to engineering problems. One principle is "Intermediary" and another is "Cheap, short-lived objects." These and a growing number of sub-principles may have the general effect of helping a person look at a design problem in different ways. This is the process aspect. But trying to apply the principles to an actual design problem will be futile unless one has abundant knowledge not only of the particular problem but other more remotely related knowledge enabling one to discover, for instance, a cheap, temporary object or material that could be placed between moving parts to mediate and not disrupt their interaction. The same is true of other domain-specific problem-solving heuristics—for instance, the geometric and physical knowledge needed to make effective rather than time-wasting use of Polya's (1945) suggestion to draw a picture to aid in solving a mathematics problem or the syntactical knowledge and skill required to make use of Christensen's (1963) "generative rhetoric" in producing more readable and effective sentences. In summary, learning to think like a specialist in a variety of disciplines and lines of work has potential to add greatly to a person's cognitive resources for productive thought; heuristics and principles can provide a way into different kinds of specialized thinking, but they need to be intimately linked to substantive knowledge and skills. Commercial instructional materials as well as theoretically-grounded "scripts" (Kollar, Fischer, & Slotta, 2007) seldom come close to the level of detailed heuristics and substantive content required to help the learner begin to "think like" a practitioner of the subject being taught. The theme of this year's Summer Institute—save lives, save the planet—brings in an incredible variety of specialties and specialized knowledge. Work on this theme will expose students to many different kinds of specialized thinking but it will be important to keep the ways of thinking attached to substantive knowledge.

Embedding Practical Skills in Knowledge Building

Many kinds of specialized thinking have a practical skills component, often including manual skills. Craft skills, obviously important in "thinking like" an expert craftsperson, are also important in more academic disciplines. There is the chemist's craft skill in diagramming molecules and also skill in handling laboratory glassware, the electronic engineer's skill in producing and using wiring diagrams and also neatly soldering connections, the biologist's skill in preparing slides and using a microscope. To a some extent craft skills can be learned separately from the conceptual part of specialist thinking, but for the student, the craft skills enable the kinds of experimentation and exploration that develop the conceptual part. Therefore, they commonly take precedence. This can be detrimental, however, if the craft activity gains so much attention that the conceptual part gets no attention. This seems to be a common phenomenon in school learning activities, where, for instance, producing a poster to display what has been learned leads to almost all the attention being devoted to the craft of poster-making and little to the content. Elementary school students will talk about "making" an experiment, with little sense of a knowledge building purpose or of scientific thinking (Carey, et al, 1989).

In computational thinking— learning to think like a software developer—the related craft skill is, of course, skill in producing code that actually works. In some cases, this is the whole point of instruction, but education for computational thinking has the larger purpose of using this craft skill for more general educational purposes. Thus, there is having students create computer games to teach oceanography (Yarnall & Kafair, 1996) or using robot programming in mathematics or social studies (Khanlari & Scardamalia, 2019). The difficulty that commonly arises, however, is that the programming activity is so motivating and absorbing that it is difficult to get students to give attention to the academic subject matter, which typically lacks the sensational appeal and challenge of the programming activity. The study by Yarnall and Kafai (1996) illustrates the problem dramatically. Grade 5 students were asked to produce computer games to teach younger students about the ocean environment. Although the activity proved highly motivating, the games students produced were simplistic question-answer games (thus a step backward from the intended constructivist learning approach) and the online discussion dealt with programming and avoided scientific issues. Similar results have been reported with the very popular programming environment, Scratch. In summary, programming activities by school students develop craft knowledge of programming but little disciplinary knowledge, knowledge of gaming or whatever art is involved, or higher-level computational thinking. Developing craft knowledge may be sufficient justification for giving programming a place in the curriculum, but it should be possible to go beyond this, to make programming a more significant contributor to general educational development.

Knowledge Building is the obvious way to broaden the scope of intellectual engagement, but it is still likely to suffer in a head-to-head competition with coding activities, such as those that have made Scratch not just a coding language but the basis for a vast community of students doing interesting things with it. A potential solution is to start Knowledge Building *before* the programming activity, which then needs to be carried out within a context of collaborative knowledge building—sustained creative work with knowledge and ideas in the domain of study.

As a hypothetical case, let us assume that the students have previously learned the basics of Scratch and have used it to produce simple graphics. The topic of study now is plant nutrition. If Scratch is brought into an initial stage of work on this topic, the result is likely to be pictures of plants, in the best cases animations showing the development from seed to leafy plant and then to flower or fruit. In the process little or nothing will have been learned beyond simple facts of plant development. If, however, Knowledge Building is done from the beginning before there is anything to do with computation, there will be questions, consulting of authoritative sources, experiments, more and deeper questions, and much presenting and building on students' own ideas about plant nutrition. Questions will arise about how plants can get nutrients from the earth whereas animals cannot and students will encounter the idea that plants produce their own food through something called "photosynthesis," which is an idea that calls for considerable explanation building. At some point the question is introduced (hopefully by a student): Is there any way we could use Scratch to help build our understanding of plant nutrition? This then becomes a question to pursue as part of this particular knowledge-building project. Ideas brought up will be considered and tried out in Scratch. Animations may now show x-ray views of what is hypothesized to go on in leaves, roots, stems or trunks. These may now be discussed not only from the standpoint of how the program was written but more crucially from the standpoint of how well the animation fits with known facts. Improvements will not be limited to improvements in style and program operation but will be progress toward better explanations of the phenomena represented. What students carry away with them from the experience should include increments in computational thinking and also a substantial advance in understanding of the plant world surrounding them.

Computational Thinking in a World of Neural Nets

The discussion so far has ignored the elephant in the room of computational thinking—artificial neural nets or ANNs. These are behind most of the news-making innovations in digital technology—driverless cars, handheld speech translators, face recognition, championship players of board games—and promise to play a rapidly increasing role in our lives. The computational thinking involved is of a fundamentally different kind from the kind involved in older software and that students are learning in school (Gurney, 2001). This is not to say that what students learn in working with Scratch or programming a mobile robot is useless, but it is definitely 20th, not 21st century computational thinking. Schools ought to be addressing the revolutionary implications of ANNs not only through modernized work on computational thinking but through a more general overhaul of disciplinary education. ANNs are part of a closely related family of developments in contemporary thought that include complex systems theory (Wilensky & Jacobson, 2014), dual process theory in cognitive science (Stanovich, 2004, pp. 31-80)), "hot cognition" (Thagard, 2006) in which emotions are not just influences on thought but are an integral part of it, a neuroscience in which real neural nets are featured players, and an approach to learning that gives the intentional development of intuitive knowledge a vital role (Brown, 2017). How to address all of these in a way that recognizes their interconnectedness and yet is adapted to the capabilities of students at different stages of development is a challenge far beyond the scope of this paper. While no educational approach has an off-the-shelf response to this challenge, Knowledge Building is arguably the approach best equipped to develop one.

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Peer feedback and Sense of Community in a blended university course

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Abstract: The aim of the present study was to analyse the students' participation and the association between their participation and their Sense of Community (SC) in a course at University designed according to a teaching method based on peer feedback. Twenty-eight students attending the Guided Practice Exercise (EPG) of Learning Psychology and digital technologies of the degree course in Psychological Sciences and Techniques were involved. The activity of the EPG took place in a blended form with the support of Knowledge Forum (KF). The teaching method was inspired by the Knowledge Building model and based on peer feedback. Data concerning students' participation in terms of writing activity was detected through a specific software called Analytic Tools. The KF notes were divided into containing feedback vs. not. Feedback notes were segmented into syntactic units and labelled by two judges using a coding scheme which provided: Positive aspects, Negative aspects, Proposals for improvement, Questions, Other. The SC was detected by administering the Classroom Community Scale (Rovai, 2002), adapted by Perrucci, Cacciamani and Balboni (2016), composed by two sub-scales: Connection and Learning. Results evidence a statistically significant correlation between the Proposals for improvement feedback and the Connection subscale. Implication of these results are discussed.

Introduction

In psychological literature, the Sense of Community (SC) refers to the perception of similarity and strong interdependence among the members of a group, perceived as reliable (Davidson & Cotter, 1991; Sarason, 1974). The SC has been extensively studied in online courses in higher education because the lack of physical presence may cause, in the students**,** feelings of isolation from their professors, from classmates, and from the university context, with consequent risk of abandoning (Rovai, 2002; Rovai & Wighting, 2005). When the SC is present in online courses and if students are given the opportunity to create connections to the course community, they are more satisfied and report higher levels of learning (Hsieh, Chang & Smith, 2008; Tsai et al., 2008). According to Lin and Gao (2020), the SC not only increase classroom participation and deep learning (Garrison, Anderson, & Archer, 2010), but also enhance students' ability of managing stress and promote emotional well-being (Stubb, Pyhältö, & Lonka, 2011). SC in online course can be favoured supporting online interaction among the students. Cacciamani, Cesareni, Perrucci, Balboni and Khanlari (2019) showed, for instance, that students' SC - in the membership dimension - can be promoted thanks to a student with the role of Social tutor, facilitating online interaction. One of the most common used tools to measure the SC in university courses is the Classroom Community Scale (CCS), developed by Rovai (2002) which can be used in both F2F and online courses. The CCS is a self-report questionnaire composed by two sub-scales, Connection and Learning, measuring respectively the social community dimension and the learning community dimension. The social community dimension represents students' feelings about the community, including their spirit, cohesion, trust, interactivity, interdependence, and sense of belonging. The learning community dimension includes the feelings of the community members regarding the degree to which they share group norms and values and the degree to which belonging to the group meets their educational goals and their expectations about their formative needs (Rovai, Wighting, & Liu, 2005).

Peer feedback is defined as a communicative process in which those who learn, talk to each other about the performance and the standards required in an activity (Liu & Carless, 2006). Learning benefits have been highlighted in the literature, thanks to the peer feedback exchange. Liu and Carless (2006) identified some peer feedback benefits that motivate the use of this method. They primarily concern the active role that is attributed to students in the management of their own learning, when they are involved in giving and receiving feedback. In fact, students can better self-regulate the own learning, because of receiving feedback from their own classmates, both

thanks to the fact that, commenting others' work, they acquire a more objective knowledge of evaluation standards, which can be also used to evaluate their own products (Cacciamani, Perrucci, & Iannaccone, 2018).
Recently, a teaching method called Progressive Design Method (PDM), inspired by the Knowledge Building (KB) model (Scardamalia & Bereiter, 2003; Scardamalia & Bereiter, 2010) and based on the progressive elaboration of projects by the students and on peer feedback in an online environment, has been developed by Cacciamani (2017). The PDM has been defined through the following principles (described later in a more detailed way): 1. Students as members of a KB Community; 2. Critical Theoretical Model Analysis; 3. Critical Case Analysis; 4. Progressive improvement of the project; 5. Distributed Feedback; 6. Recursive Design.
Despite the relevance of peer feedback and SC in online courses at University, studies exploring the association between the two aspects seems lacking in literature. This study, using the PDM in a blended university course, aims to explore the following questions:

1. Is there any association among students' participation in terms of writing activity in the online environment of the course and the SC?
2. What kind of feedback are used by the students?
3. Is there any association among the number and the extension of feedback provided by the students and the SC?
4. Is there any association among the kind of feedback provided by the students and SC?

Method

Participants

Twenty-eight students (20 females, age M (DS) = 22.39 (3.5) attending the Guided Practice Exercise (EPG) of Learning Psychology and digital technologies of 2nd year of the degree course in Psychological Sciences and Techniques at the University of Valle d'Aosta participated in the research. All participants provided their informed consent.

Online environment

The activity of the EPG took place in a blended form with the support of the online environment Knowledge Forum (KF). KF is a web-based discourse medium specifically designed according to the 12 principles of the KB model (Scardamalia & Bereiter, 2010), to support production and refinement of ideas and to advance understanding of the world through social interaction (Scardamalia, 2004). KF, with its specific design, can facilitate development of KB communities, and provide opportunities for students to act as knowledge workers in an open space (Bereiter & Scardamalia, 2014; Scardamalia, 2004). In KF it is possible to create specific spaces -called "views"- that can be used to organize the discourse about specific topics. In each view the students can insert notes through written text and graphs and images can be added. These notes can also be connected to one another via links. In this case, the notes are called "build-on" meaning that they represent an advancement of the knowledge-building activity. Specific applets called "Analytic Tools" allow the activities of the students working in KF to be traced, in terms of writing and reading activity.

Context

The course was organized with reference to the PDM according to the following principles and activities (Cacciamani, 2017):
1. Students as members of a KB Community: students were organized within a KB community and worked collaboratively in teams to design a project.
2. Critical Theoretical Model Analysis: the KB model was analyzed by students working together in groups to identify the possible advantages and critical aspects in the hypothesis of applying these principles in Italian schools. Reflections were shared in KF, in a specific view.
3.Critical Case Analysis: students analyzed implementations of the KB model in different contexts to identify points of strength and weaknesses and ideas to improve them.
4. Progressive improvement of the project: the elaboration of the project was organized in steps that allowed the team members to progressively improve their project. The steps were: (1st step) identifying the context, the participants, the objectives (in terms of skills to be developed through the project), and a title for the project; (2nd step) defining the phases of work, the timing, the instruments and the resources; (3rd step) choosing the method to be used for assessment and evaluation of the project, in coherence with the previous aspects; (4th step) creating an

advertising spot through a video or a Power Point, to explain the reasons for adopting the project by a possible stakeholder.
5. Distributed Feedback: for each step the partial created product was organized in a Power Point presentation and published in KF (except for the advertising spot that received an oral feedback), where each member of the community could analyze the others' team product and provide a feedback with the following scaffolds: Positive aspects of the project, Negative aspects of the project, Questions, Proposal for improvement of the project.
6. Recursive Design: after receiving feedback in KF, each team was given time to reflect of any ideas that emerged through the feedback and to introduce changes to their project.
The EPG was then developed in eight F2F meetings of three academic hours each, according to the described above principles. Students could continue the activity of reciprocal feedback also online at home.

Procedure

Data concerning students' participation in terms of writing activity (notes and build-on) was detected through a specific software program called Analytic Tools (AT). AT provides summary statistics on the activities in each view in the KF database. In order to identify the notes containing feedback two different judges analysed the content of each notes and classified it in "note with feedback "and "note with no feedback. The 130 KF notes containing feedback were then segmented into 384 syntactic units by two independent judges. The content of the segments has been labelled by the same judges by means of a coding scheme which provides: *Positive aspects*, *Negative aspects*, *Proposals for improvement*, *Questions*, *Other*. The degree of agreement was good (Agreement index = 87% and Cohen's K = .80). The number of segments containing feedback was considered a measure of the extension of the feedback. The SC was detected by administering in the penultimate meeting of the EPG the CCS (Rovai, 2002) adapted by Perrucci, Cacciamani and Balboni (2016), consisting of 20 items rated on a 5-point Likert scale and formed by the two sub-scales: Connection (12 items) and Learning (10 items).
The correlations between the investigated variables were calculated with the Spearman's Rho coefficient.

Results

With reference to the first question of inquiry we have not found any association among students' participation, in terms of notes or build-on written in KF, and SC. Concerning the second question of inquiry, results showed the prevalence of feedback focused on *Positive aspects* of the projects (142 segments), followed by *Negative aspects* (26 segments), *Proposals for improvement* (24 segments) and *Questions* about the projects (17 segments). Third, there was no statistical correlation between the SC and the number of notes containing feedback or number of segments containing feedback. Finally, with reference to the kind of feedback provided, the correlation with SC are presented in Table 1

Table 1: Correlation among kind of feedback and SC

	Global SC	Connection subscale	Learning subscale
Positive aspects	.211	.242	.245
Negative aspects	-.073	-.082	.029
Proposals of improvement	.356	.478**	-.025
Questions	-.103	-.181	.239
Other	.120	.181	.067

**p<.01

As you can see, a statistically significant correlation was found between the Proposals for improvement feedback category and the Connection subscale (Rho = .478, $p = .01$).

Discussion

The aim of the present study was to analyse the students' participation and the presence of associations between their participation in KF and their SC in a blended course at University, in which PDM was used. Results showed the prevalence of feedback focused on positive aspects of the projects, followed by negative aspects, proposals for improvement and questions about the projects. This situation seems to describe a not particularly critical approach from the students toward the projects of their classmates, also if *Negative aspects* and *Proposals for improvement* feedbacks are used. Also, an association between *Proposals for improvement* and the Connection factor of SC emerged. Connection in the CCS is the sub-scale measuring the Social community dimension. We can hypothesize that this association may be due to the fact that engaging in producing ideas for colleagues' projects is a prosocial behaviour that contributes to the development of the SC, but also that high levels of SC stimulate the implementation of help behaviours such as writing comments to help to improve. It seems, indeed, that students assumed the KB perspective: in peer feedback activity, expertise is distributed among groups of work and all groups gain in knowledge through their participation in a joint effort to ameliorate the projects, consistently with the Symmetric Knowledge Advancement principle of KB model (Scardamalia & Bereiter, 2010). From one hand, then, connection among participants could help the assumption of the KB perspective, from the other hand, the assumption of the KB perspective, an promote connection among participants. The lack of correlation among the different kind of feedback and the Learning factor of SC is also interesting. It is possible that students considered their activity more oriented to build products of common knowledge (the group project) rather than focused on individual learning. The Learning subscale of CCS, then could be unable to capture the students' focus on knowledge building

Further investigations will have to study the possible reciprocity of this phenomenon by examining also the relationship between the type of feedback received and the SC. In addition, another direction of inquiry could be focused on contrasting these results with other tests and in other samples, or larger samples, adding some variables that provide information on the quality of the feedback. Finally, it could be interesting to develop a scale that can measure SC with reference to knowledge building, to verify the possible correlation with the kind of feedback provided.

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Examining Cognitive Collaborative Annotations Contributions in Knowledge Forum through Idea Magnets tool: Effects and Future Directions

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Abstract: Global issues facing society produce abundant information for students to tackle in complexity in order to grasp understanding. By fostering societal discussions around issues in politics, sustainability and development of humanity, student's learning needs to be supported. Students were to support building arguments from web sources in order to procure data; to support their theories. The study looks at the works of a grade six Knowledge Building community and their approach to world issues. How are student's conceptual understanding in Knowledge Forum utilized through the Idea Magnets tool (Chen 2019). This snapshot study analyzed the Annotation category types (Chen 2020) & the metacognitive annotation types (Li et al 2006) and looks at the potential benefits to support's students learning. We utilized Crowd layers analytics to report results. The results suggest that the students did not produce metacognitive rich annotations, and mostly presented "I Know" annotation types meaning "knowledge" rich annotations were not evident. The author describes what she entitles as void phenomena and the paper theorizes next steps and future work to mitigate these results.

Introduction

Ethically complex, ill structured problems plague humanity daily. There is no simple reasoning or solution to solving these problems with a quick, clear cut solution. Zielder et al, (2005) found that students experience learning difficulties due to complexity, uncertainty fails to identify easy solutions and are usually stuck. Eggert (2017) notes "high cognitive processing demands on students due to scientific and interdisciplinary knowledge yet there is evidence of engagement in various information search, and integration, reasoning and decision making." (p.139). So how are students to tackle authentic and ill structured social issues. With varied information available to students, difficulties are often attributed to failure to maintain a "shared focus" (Veerman, Andriessen, & Kanselaar, 1999). Berners-Lee, Bizer, & Heath (2009) note that an area unexplored in collaborative learning systems is linked data, a method that uses the web to enable data from different sources to be connected and used in new contexts. Building coherent knowledge has become increasing challenging because of the fragmentary character of much digitally mediated information. Knowledge Forum provides a facilitation model to enhance the social construction of understanding of complex ideas and concepts through online community dialogue (Lipman 2003; Scardamalia & Bereiter 1996; Wenger 1998). According to Lipman (2003) "children collaborating with one another allows understanding to grow beyond the material world but also of persona and the ethical world around them" (Wegerif, 2007, p.13).This method uses the web to enable data from different sources to be connected and used in new contexts. One method of understating is through tacking these issues with collaborative annotation. Collaborative annotations have the potential to engage students in actively and meaningfully reshaping received ideas, addressing logical weaknesses in arguments, synthesizing ideas, and assessing ideas for application to complex problems (Wolfe, 2002). In order for ideas to be continuously improved, participants must take collective responsibility for knowledge advancement and constructive uses of authoritative sources.

The goal of this research was to understand the linkages of learning spaces. Students were introduced to the tool Hypothes.is in order to see how they can work with any web object and were able to annotate and highlight. Whatever students wished to take note of, they were shown it would be directly brought back to the community to be worked upon and to further student understanding. Within the Knowledge community, students were learning the importance of referencing, as well as making data claims. The context for improving uses of annotations will be a knowledge building community (Scardamalia, 2002) in which students typically use web resources to address issues they have posed and that lead them to reference material well above their grade level.

The research will focus on forms of annotation and collaborative work with self-selected student texts from web resources. Issues to be addressed: What texts do students search for and how many are annotated? What form do annotations take? To what extent are annotations productively shared and built on to deepen or in other ways extend the meaning of the text? Are annotations enriched through collaborative work?

Methods

In the present study, we aimed to make use of Collaborative annotations as a learning strategy to promote idea advancements, reasoning and decision making on world issues. The belief was that students would-be well-rounded citizens, and through the work within the Knowledge building community could help students in breaking down difficult concepts to grasp.

As an exploratory approach, twenty-four students were learning about Global /World issues and decided as a community to focus on six themes: Poverty, Sexism, Governments, GDP/ Inequality, Climate Change & Venezuela. Students self-organized within groups based on topic of interest but were free to contribute to any group and collect any data. It was important to introduce to the students the idea of data claims. The instructor was finding that students were bombarded with a lot of fake news, misinformation and were making claims about the world. Their teacher noted a gap in understanding and pointed out the importance of why data was useful to support their thinking and claims. As these students were learning about these topics, students were to gather data in order to facilitate inquiry, facilitate argumentation and theories through multiple perspectives. These students had over five years of Knowledge Building pedagogy; however, they were not well versed within an in-depth understanding of the Knowledge building principle Authoritative sources.

Students worked on the course for over two months but did not contribute to annotations on each classroom session. Crowd Layers "CROWDLAAERS" (Capturing and Reporting Open Web Data for Learning Analytics, Annotation & Education Researchers) is an analytic tool and dashboard that captures the discourse layers produced by communities via Hypothesi.s. This tool provided an overview and observation of an entire community, observing the online documents utilized by them. By visualizing the collaborative activity of a community, the tool provides complementing graphics that show connections regarding "annotations, participants, documents, threads, days and tags that reports and captures learning analytics. (Kalir, J. 2020).

Utilizing the framework of Chen et al. (2020), they developed annotation types or reading and response annotations in order to examine student's response and to see if their response types support community scaffolding. Here we are utilizing this classification system to determine how in-depth they are working with the knowledge (information) they have accessed. The annotations were only analyzed based on the reading annotations. Within this study no student directly responded to another student's annotation.

Table 1. Chen et al. (2020) - Description of Annotation Types

Annotation type	Reading Annotation
I know	Provide understanding or known facts of an annotated text
New knowledge	Identify new knowledge learned from an annotated text
Don't understand	Indicate an annotated text that does not understand
Different ideas	Indicate the text that is different from what I think, and give reasons
Additional Information	Provide supplementary information for an annotated text by using an online search tool in WCRAS
I want to say	Give comments to an annotated text and invite other students to discuss their ideas
Correction	–

As well, this study utilized the framework of Le et al. (2006) to determine the metacognitive, cognitive and social processes of annotations. This framework assists in understanding how successful the inquiry and knowledge synthesis of the information students have acquired and student learning outcomes.

Table 2. Li et al. (2006) – Metacognitive Coding Scheme

Dimension	Label	Code
Cognitive1	c01	Agree
	c02	Inform
	c03	Elaborate
	c04	Classify
	c05	Illustrate
Cognitive2	c06	Question
	c07	Criticize
	c08	Summarize
	c09	Synthesize
	c10	Evaluate
Metacognitive	m01	Reflect
	m02	Manage
	m03	Plan
Social	s01	Appreciate
	s02	Request
	s03	Encourage

Analysis and Results

The Knowledge building community made a total of 144 total note contributions to the community. While we are not directly analyzing these notes, it is important to understand the make-up of information regarding the community. Figure 1 examines the results from the Crowdlayer analytic tool. As we can see a total of 29 Annotations were created within the community. Of the total 29 annotations, 3 were created by the researcher, and 26 annotations were created by the students. Within the Collaborative Annotation community consisted of 18 total participants; 17 were students and 1 was the researcher. 19 total websites were utilized and acted as authoritative sources that students incorporated. Of the total documents, the researcher engaged with 3 documents during the initial presentation in order to show students the various ways of how they can utilize web objects.

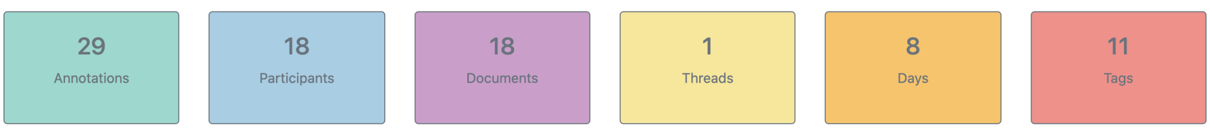


Figure 1. Crowd Layers Analytics Results.

The instructor provided students with 6 links to annotation and choose from in order to assist with reducing cognitive load, but students actually did not utilize any of these and instead chose their own resources to annotate. Students engaged with 18 different websites, which then enacted as authoritative sources. We can see that one thread occurred but with a closer inspection, we noted that this was in fact the researcher's demonstration to the students of how to utilize the thread but no one student attempted to make a thread. Students engaged with 11 tags and 5 unique tags. Students tags mostly reflected around climate change concepts (#CC, #Climatechange). One student analyzed gender equality and looked at an ad for sports and created the following three tags (#nike, #serenawilliamsequalityjustdoit and #POV for an acronym of point of view).

With the analysis of the 29 annotations, the author examined only the 26-student annotations and categorized them based on the Annotation types of Chen et al. (2020).

Table 3. Annotation Type Results

Annotation Type	Coded Annotations Found	% of Total Annotations
I Know	1	4%
New Knowledge	7	27%
Don't Understand	1	4%
Different Ideas	4	15%
Additional Information	3	12%
I want to Say	10	38%
Correction	0	0%

As we see in table three, most student Collaborative Annotations just incorporates information they found, and just contribute "I want to say". In these annotations' students see an interesting idea, but just want to introduce it without producing an idea with much substance; and utilize the text they analyze as their words as information they also want to incorporate. However, we also see that 27% of annotations produce new knowledge learned from an annotated text. It is noted that here students contribute new ideas based on the information they have gathered and add new knowledge to advance their own understanding

As we can see from the results from Table 3, no student corrected any of the information they found online. This is interesting as students do not believe they should be challenging Authoritative sources. The author believes that students still highly regard authoritative sources,

Table 4. Metacognitive Coding Scheme Type Results

Metacognitive Dimension	Code	Number of Annotations in Category	% of Total Annotations	Total of Annotations per Dimension	% of Annotations Per Dimension
Cognitive 1	Agree	7	27%	15	57%
	Inform	3	12%		
	Elaborate	5	19%		
	Classify	0	0%		
	Illustrate	0	0%		
Cognitive 2	Question	1	4%	4	15%
	Criticize	1	4%		
	Summarize	0	0%		
	Synthesize	2	7%		
	Evaluate	0	0%		
Metacognitive	Reflect	2	7%	2	8%
	Manage	0	0%		
	Plan	0	0%		
Social	Appreciate	4	15%	5	19%
	Request	0	0%		
	Encourage	1	4%		

As we note in table 4, most students produce annotations under the cognitive 1-dimension category at 57% of total annotations. Most students' annotations were coded as "agree" with the text they annotate, at 27%. Within the same dimension 19% of students chose to elaborate which allowed for student voice to explain on how they understood the text they were utilizing and the connection it had to world issues. As a first iteration, it makes sense that 15% of total annotations "Appreciate" as they may have shared the information in a social manner. Many students may have found information that was of interest, but it did not advance any knowledge in the community.

To get a bit more of an in-depth understanding, by looking at some Collaborative annotations within the “Poverty as a world issue” topic, it complements the framework findings we see in the tables above. As we note, there were not many annotations (26) in comparison to notes (144). As we can see in the example below, some students chose to utilize sharing ideas not through Collaborative Annotation. However, in highlighting the notes below -we see a bit of a disconnect and no interaction between notes & collaborative annotation. This highlights a problem, that these activities seem to be in contrast when instead they should be complementary learning actions.

Student O co-authored a note that stated:

“Nearly 1/2 of the world’s population ,almost more than 3 billion people ,live on less than $2.50 a day. More than 1.3 billion live in extreme poverty @ less than $1.25 a day”. There are 11 horrible facts about poverty https://www.dosomething.org/us/facts/11-facts-about-global-poverty”

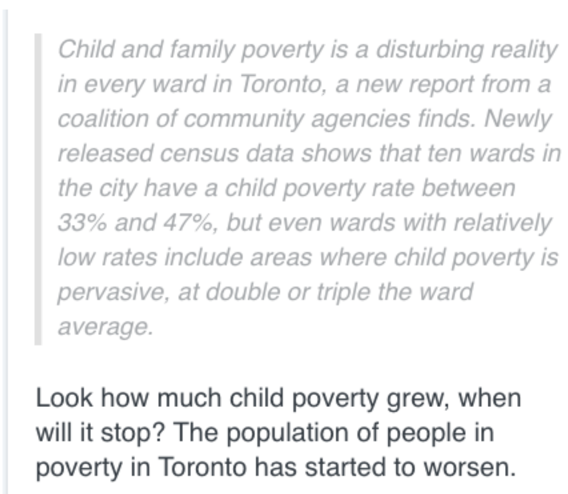
Now in the example above the student did not utilize the Collaborative annotation tool near the beginning of the term and mistakenly thought that this was the only way to share data was to paste links into notes. The student was so clearly perplexed and moved by these statistics. We can see the student was driven to tell a story by utilizing data, to support his theories. While the student was shocked this led to the student wanting to continue to pursue data at poverty at the local context.

Furthermore, with the community, we see Student E wrote the following note asking for help from her community about additional statistics on poverty.

“Poverty is really bad. I think most people really want to get rid of poverty because it's effecting many people's lives. Some countries are spending tons of money on poverty, but the question is why is there still so much poverty? Also, if anyone has some data or ideas about poverty please tell me.”

While student E had asked for additional data, we see that too wanted to share ideas about poverty. They had a thought and understanding of how bad it is but wanted to further their own understanding.

Student O Had written an Annotation Of the following


Child and family poverty is a disturbing reality in every ward in Toronto, a new report from a coalition of community agencies finds. Newly released census data shows that ten wards in the city have a child poverty rate between 33% and 47%, but even wards with relatively low rates include areas where child poverty is pervasive, at double or triple the ward average.

Look how much child poverty grew, when will it stop? The population of people in poverty in Toronto has started to worsen.

The produced results provide interesting analysis, as we see a chain of ideas, and notes surrounding poverty, yet none are advancing any critical knowledge work. We want to term this concept as the void phenomena. While students have some overlapping ideas, it seems that they do not directly interact begin multi-modal learning objects or may be cognitively overwhelmed by different access points of information.

It seems like students are not actually engaging with each other's notes or annotations and it can be that students may not yet be used to or accustomed to checking these. While there is the Magnet Note (chen 2019) feature, we note that while students dragged their annotation and made use of the Magnet Note - they did not utilize the tool as intended.

Discussion

While this study notes that there was no evidence that students directly worked with Collaborative annotations, we find that these are emerging challenges remaining to be conducted with new iterative practices incorporated on future studies.

One idea with student' learning processes should be to incorporate peers' annotations with as much importance as note creation within a Knowledge building community. Students need to be mindful of their learning outcomes and recognize that multiple multi-modal objects exist and needs to be considered within the community. Students need to not just obtain web objects but continually work and improve on their ideas to see idea improvement and iteration based on these introduced web objects and authoritative sources. While we can successfully say student did work with web objects, there is still more knowledge work and research to be done in order to improve these results.

Future iterations should assist students in demonstrating that they can disagree with an authoritative source and compile more information and data to be incorporate and remixed within the community. As also viewed in the work of Chen et al (2020), better collaborative annotation struggles strategies need to be incorporated and constructed in order to dictate better evaluation of student's perceived benefits in the learning context. As this is one of the first studies with elementary students use of Collaborative annotations, this paper has developed more questions than answers to iterate on new Design documents to be created in order to establish more metacognitive and better integrated Collaborative annotations.

Additionally, future research will examine the criteria the learners use to select annotations. The researcher will hope to examine future cohorts and studies to better examine the relationship between information types and attached annotation.

While Knowledge Building as an educational act can incorporate new epistemic markers, reimaging how new ways knowledge coherence, and transmission can be utilized especially during Covid-19. As misinformation is created and spread faster than we have ever experienced, opportunities for collaborative annotation can develop a new pivotal point to understand we would need to reimage how to develop new ways to gauge student understanding of facts within their own Knowledge schemas. This paper allows for future work to build on of these results allowing for new iterative designs to be established. The author believes that future work should incorporate the use of scaffolds in conjunction with collaboration annotation may help support students to develop more metacognitive & new knowledge coherence opportunities.

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The Idea-Friend Maps

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Abstract: This paper describes the development of representations based on a learning analytics tool, Idea-Friend Maps. It is designed to provide students with scaffoldings on three key questions that students may have when creating knowledge-creating dialogue: (1) How to work like researchers, to pursue different but related ideas? (2) How to identify the current state and future direction of the community knowledge? (3) How to create new knowledge by crossing knowledge boundaries? The inspiration is from the good moves in knowledge-creating dialogue proposed by Bereiter and Scardamalia. Moreover, from the *word* network exported from KBDex, three levels of Idea-Friend Maps are redesigned, including the group, community, and knowledge creation-levels. Furthermore, student inquiry into Idea-Friend Maps is integrated with social configurations (interactive and opportunistic collaborations). In addition to a conceptual framework underlying the Idea-Friend Maps design, this paper also elaborates upon the features of Idea-Friend Maps and reports the results of two cycles of implementation involving students.

Introduction

Equipping learners with capacities for knowledge creation and innovation has become a significant challenge facing education (OECD, 2017). *Knowledge Building* is a major educational-model in the learning sciences developed by Bereiter and Scardamalia (1993) based on decades of research. It focuses on knowledge-creation in a community as a collective effort. To support such creative community work, an online discussion platform, Knowledge Forum®, was designed to allow students to realize a series of knowledge works, such as posting problems, offering explanations, testing ideas, and conducting a sustained pursuit of inquiry, so that they can rise above and achieve collective advances (Scardamalia, 2002). Because of the central role of dialogue in knowledge-creating communities (Von Krogh, Ichijo, & Nonaka, 2000), promoting knowledge-creating dialogue is one of the urgent problems in the knowledge-building community. Thus, this paper provides a brief report of the development of representations from a learning analytics tool, Idea-Friend Maps (IFM), which focuses on the visualization of collective ideas on Knowledge Forum to promote knowledge-creating dialogue.

Knowledge-Creating Dialogue

Bereiter and Scardamalia (2016) proposed seven types of "good moves" for knowledge-creating dialogue, including *Problem Definition*, *New Ideas*, *Promisingness Evaluation*, *Meta-Dialogue*, *Comparison*, *Critical Discourse*, and *Higher-Level Ideas*. Great endeavors have been devoted to engaging students with good moves in knowledge-creating dialogue. For instance, to facilitate dynamic diffusion of *New Ideas* (i.e., introducing new ideas and integrating them with current community knowledge), Zhang, Scardamalia, Reeve, and Messina (2009) examined three kinds of social-configurations (fixed groups, interactive groups, and opportunistic groups). Opportunistic groups (students working temporarily in groups for emergent goals) were found to yield the best learning outcomes. However, further studies are still needed to explore how such emergent goals are created, just like researchers working in different groups but conducting research attachments because of common research interests.

In other practices, *Meta-Dialogue* (reflective dialogue about dialogue) has been adopted to promote knowledge-creating dialogue. For example, Van Aalst and Chan (2007) designed an e-portfolio assessment tool with four knowledge building principles to help graduate students map collective ideas. Through the comparison between students' and experts' word networks, Resendes, Scardamalia, Bereiter, Chen, and Halewood (2015) intended to help students conduct classroom dialogue for identifying new lines of inquiry. Zhang et al. (2018) designed Idea Thread Mapper so that students could engage in meta-dialogue to review collective progress in extended online dialogue. Nonetheless, these examples above explored knowledge-creating dialogue only in small communities. Therefore, how to identify the current state and future direction among the large volume of online discussion notes created by large communities has aroused wide attention.

In addition, another strand of research has paid attention to the good dialogue move of *Comparison*, which denotes idea development across problems and community boundaries. For example, Yuan et al. investigated cross-classroom interaction, especially how new ideas were created in individual communities and improved by the cross-community dialogue, providing new insights into individual communities for further inquiry (Yuan & Zhang, 2020; Yuan, Zhang, & Chen, 2019). It is considered a novel design for Higher-Level Ideas (working collaboratively to develop an idea beyond the current state) by crossing community boundaries. However, from another perspective, creating new gaps and promising ideas on the boundaries of problems and theories might be another contributor to *Higher-Level Ideas*.

To sum up, substantial advances have been made in driving good moves of knowledge-creating dialogue through novel pedagogical and technological designs. Nevertheless, the following three questions deserve more effort: (1) How to work like researchers, to pursue different but related ideas? (2) How to identify the current state and future direction of the community knowledge? (3) How to create new knowledge by crossing knowledge boundaries?

KBDex for Visualization of Knowledge-Creating Dialogue

KBDex (Oshima, Oshima, & Matsuzawa, 2012) has been adopted in extensive research to visualize the process of knowledge-creating dialogue. KBDex is a learning analytics tool for visualizing the changing social networks of *student*, *word,* and *discourse*, as well as the centrality metrics of the three networks. For instance, in the study by Ma, Tan, Teo, and Kamsan (2017), betweenness centrality of the *student* network was employed to visualize the different expertise possessed by students, coupled with whether and how those different ideas were connected by rotate leaders (students with high values of betweenness centrality). Despite the application of KBDex to this research field, how to help students intentionally work as rotate leaders to pursue different but related ideas with the aid of KBDex should be taken into account.

To assess collective knowledge advancement, Oshima, Ohsaki, Yamada, and Oshima (2017) identified pivotal notes, which might be recognized as the current status of new knowledge, using the changing total degree centrality of *discourse* network. Furthermore, employing the *word* network for teacher professional development, Teo, Chan, and Ng (2018) expected to help teachers understand student collective discourse and reflect on how to further the boundaries of collective knowledge. Though KBDex was applied to these studies, how to help students identify the current state and future direction of the community knowledge by KBDex requires further exploration.

Moreover, the betweenness centrality of the *word* network was adopted by Yuan et al. (2019) to identify the new ideas developed through crossing community boundaries. In this situation, KBDex was also used by the researchers as well; however, additional efforts are still needed to figure out how to help students identify new promising ideas across knowledge boundaries by KBDex.

In conclusion, KBDex was adopted by researchers and teachers to visualize how relative ideas were connected, how collective knowledge was advanced, how new directions were identified, and what new ideas were created through boundary-crossing. However, little attention is paid to the application of KBDex by students. Thus, the design of external representations of KBDex is necessary for promoting good moves in knowledge-creating dialogue.

Embedded Knowledge-Creating Dialogue Moves in IFM

As mentioned before, Bereiter and Scardamalia (2016) proposed seven types of "good moves" for knowledge-creating dialogue. Some of them, such as *New Ideas*, *Meta-Dialogue*, *Comparison*, and *Higher-level Ideas*, are reconceptualized into the three key questions that students may have when creating knowledge-creating dialogue:

(1) How to work like researchers as a community, to pursue different but related ideas?
(2) How to identify the current state and future direction of the community knowledge?
(3) How to create new knowledge by crossing knowledge boundaries?

To assist students in answering the above questions, we export the *word* network from KBDex and redesign the external representations into three levels of IFM, which are the group, community, and knowledge creation-levels. Table 1 lists the types, and key features of IFM, together with embedded knowledge-creating dialogue moves and examples.

Table 1: Embedded Knowledge-Creating Dialogue Moves in the Three Questions

Questions	Types of IFM	Key features	Knowledge-creating dialogue moves	Examples
How to work like researchers as a community, to pursue different but related ideas?	Group-level	Highlighting ideas from other groups.	*Problem Definition, New Ideas, Promisingness Evaluation*	Students work in interactive groups to first identify their problems and then introducing new conceptions and promising ideas from related groups.
How to identify the current state and future direction of the community knowledge?	Community-level	Highlighting key problems of the community knowledge.	*Critical Discourse, Comparison, Promisingness Evaluation, Meta-Dialogue*	Students work in opportunistic groups to conduct meta-dialogue to criticize and synthesize different theories, identify connections between problems, and create new promising ideas.
How to create new knowledge by crossing knowledge boundaries?	Knowledge creation-level	Highlighting key problems in each research area to clarify knowledge boundaries.	*Comparison, Promisingness Evaluation, Higher-Level Ideas*	Students work in opportunistic groups to identify new gaps and higher-level ideas through crossing knowledge boundaries.

The Idea-Friend Maps

Unlike many other learning analytics tools designed for researchers and teachers, the three levels of IFM are specially designed for students. The word network exported from KBDex is the designed IFM. To provide a better picture of the IFM, we take the curriculum of the *Human Input & Output* as an example to present how students from a large Grade 5 community (n = 53) addressed the three questions under the three levels of IFM (Feng, van Aalst, Chan, & Yang, 2020). The study of the *Human Input & Output* is generally classified into eight science domains: *Food Input*, *Excreta Output*, *Gas Input*, *Gas Output, Digestive System*, *Respiratory System*, *Cardiovascular System,* and *Others*.

How to Work Like Researchers as a Community, to Pursue Different but Related Ideas?

Figure 1 depicts a group-level IFM. The red and yellow circles denote those keywords that have already been and not been discussed by the group, respectively. Among them, yellow circles near the red ones represent "idea friends" (the "friendships" are among ideas), analogous to the proximity of scientific ideas in research. For example, students in the group, who took the responsibility of *Gas Input*, first identified "small intestine" as an idea friend of "food," and then moved to the *Digestive System* for relevant information.

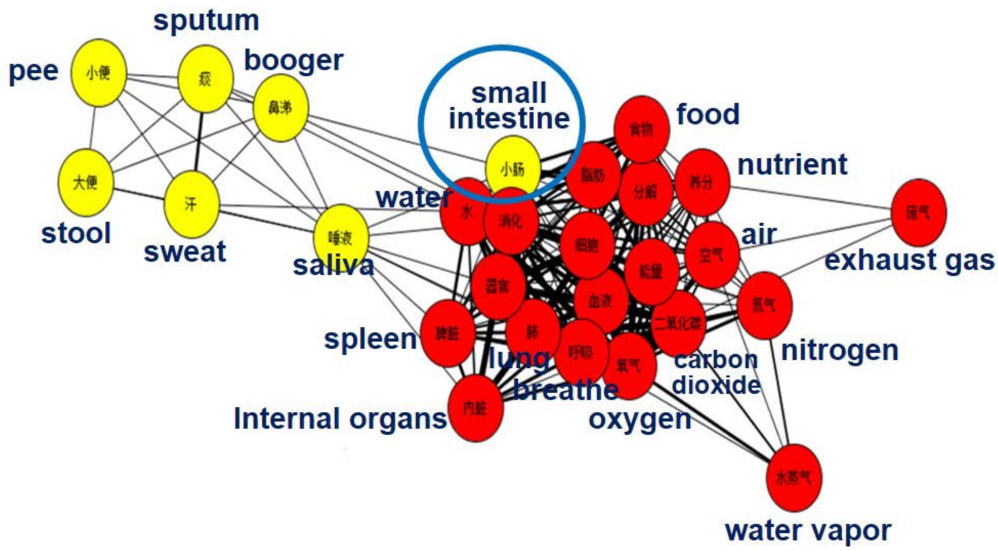

Figure 1. An example of the group-level IFM from a group who took the responsibility of *Gas Input*

How to Identify the Current State and Future Direction of the Community Knowledge?

A community-level IFM is present in Figure 2, in which the key problems identified by the community are denoted by colored circles (except yellow ones). For instance, the pink circle "nutrient" represents the key problem "How do people absorb nutrients?" It can be synthesized by students in opportunistic groups with the surrounding yellow circles.

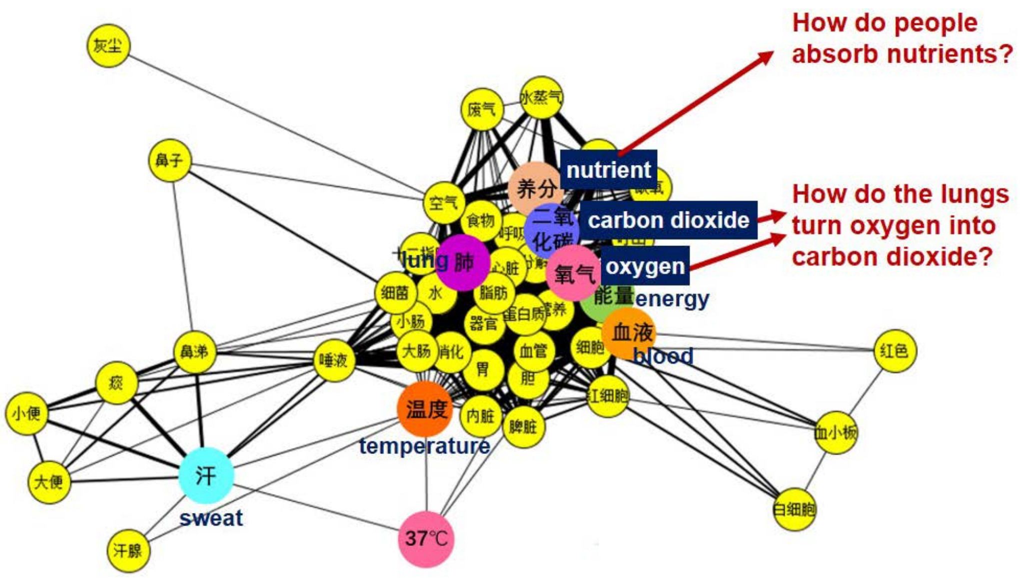

Figure 2. An example of the community-level IFM from a community

How to Create New Knowledge by Crossing Knowledge Boundaries?

Figure 3 displays the knowledge creation-level IFM. In detail, circles with the same color (except yellow ones) refer to the key ideas identified in the same problem. For instance, a new problem, “Why do we sweat after exercise but lose our body temperature?” is incurred by the connection between the red circle “exercise” and light blue circles denoting “sweat,” “temperature,” and “37°C”.

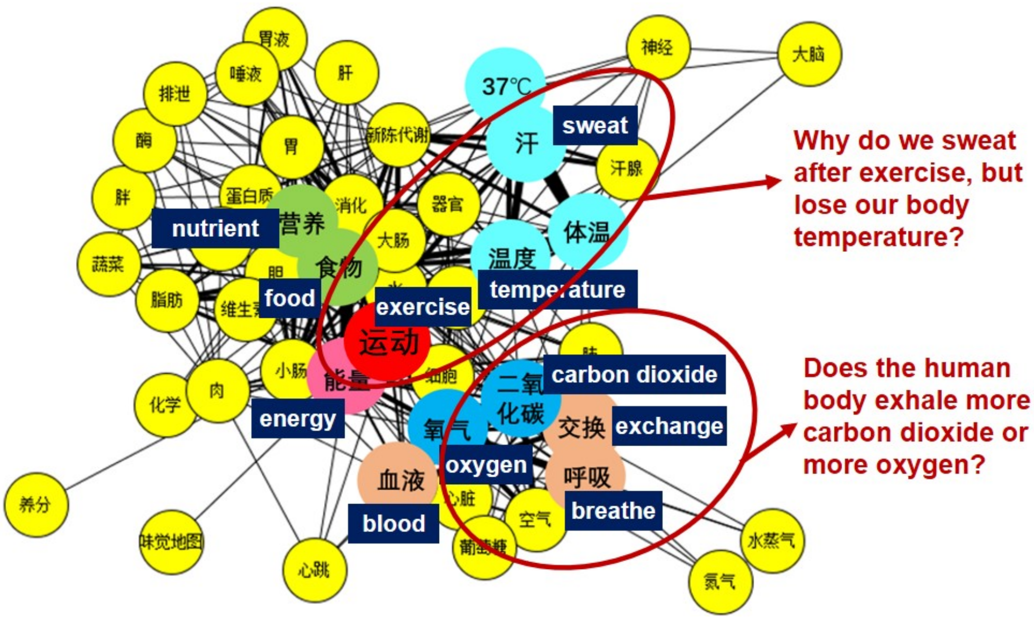

Figure 3. An example of the knowledge creation-level IFM from a community

Implementation and Results

Two-cycle design-based research was conducted among Grade 5 students when learning *Electricity* and *Human Input & Output* over two successive school semesters. It aimed to promote knowledge-creating dialogue under the three levels of IFM. Quantitative results indicate that students with the aid of the group-level IFM and community-level IFM, gained a better understanding of the science domain, achieved greater Knowledge Forum participation, and created more in-depth dialogue on Knowledge Forum than students from the regular class for the first cycle (Feng, van Aalst, Chan, & Yang, 2019). When the knowledge creation-level IFM was also implemented in the second cycle (Feng, van Aalst, Chan, et al., 2020), results reveal students’ improvements in the understanding of the science domain as well as in their contribution to the collective knowledge advancement over time.

Furthermore, qualitative results indicate the group-level IFM scaffolded high and medium-contribution groups to advance collective knowledge through bridging knowledge; the community-level facilitated student groups’ to carry out sustained inquiries; while the knowledge creation-level provided supports through synthesis, lending support, sustained inquiry, and further theory building (Feng, van Aalst, & Chan, 2020; Feng, van Aalst, Chan, et al., 2020).

Discussion

This paper reports on the development of the external representations of a learning analytics tool, which offers students the information about their changing ideas on Knowledge Forum using the redesigned *word* network from KBDex. The results from the preliminary implementation of the three-level IFM among Grade 5 students are encouraging.

Based on the proposed conceptual framework, the three levels of IFM present solutions to the three questions related to knowledge-creating dialogue that students may have. These three questions originated from the good moves of knowledge-creating dialogue (Bereiter & Scardamalia, 2016). Notably, their application is also integrated with the design of social configurations, especially the interactive and opportunistic collaboration. In the future study, more attention will be paid to the improvements of IFM and pedagogical designs, as well as how students develop progressive dialogue in the process of knowledge creation.

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Digital Storytelling in a Knowledge Building Community – An Emerging Model

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Abstract: Digital Storytelling (DS) has a history of being applied in education as a learning practice that has many documented benefits for teaching and learning across a wide variety of subjects and education levels. With a heavy focus on the use of digital devices to create short multimedia narratives that capture both the unique perspective of students as well as a synthesis of their subject matter learning. This paper will discuss an emerging model in which digital storytelling was applied to a Grade 2 laboratory school class investigating the growth and migration of salmon within their science curriculum.

Introduction

Digital storytelling (DS) is the practice of using digital devices to combine multimedia elements into a short narrative that often brings a personal element to a specific domain of knowledge. It was first introduced in an arts community in Berkeley (Lambert, 2013) in which creators of digital stories conveyed powerful messages through short videos. With social media become an influential and pervasive part of our lives, and the inevitable rise of the influencers and creators has shifted how we consume, produce and perceive knowledge (Brown, Czerniewicz, & Noakes, 2016). Digital stories have become a central component across Web 2.0 sites, with many amateurs and professionals alike turning to the likes of YouTube, Instagram and Twitter as platforms for sharing and consuming stories. When applied to education, DS has yielded many positive results ranging from increased motivation and engagement (Sadik, 2008; Van Gils, 2005), to enhanced critical thinking (Yang & Wu, 2011), creativity (Schmoelz, 2018) and even science literacy (Tan, Lee & Hung, 2013).

Despite the ubiquity of digital stories, their longevity as an artifact for teaching and learning is questionable. As such, there is potential for utilizing Knowledge Building as a framework in which the practice of digital storytelling could be embedded within. This is a result of the principles-based approach Knowledge Building takes in trying to build the necessary capacity that can sustain creative work with ideas for a community. Some of these principles include *epistemic agency, democratizing knowledge, idea diversity* and *real ideas, authentic problems* (Scardamalia, 2002). Arguably, by increasing the *epistemic agency* that students have in their own learning in the face of authentic problems you can draw upon a community's collective knowledge and input in creatively working with ideas to develop solutions. At the core, Knowledge Building asks a community to actively question, challenge and reconstruct knowledge to build new knowledge as a group. By combining the practice of digital storytelling and the principles behind their creation to a Knowledge Building community there is potential to complement and enhance the goals of Knowledge Building pedagogy. Therefore, this study aims to answer the following questions:

(1) How can DS practices aid students in sustaining creative work with ideas?
(2) How can DS be appropriately combined with Knowledge Building theory to enhance student learning?

Methodology

Research Context and Subjects

A design-based research (Brown, 1992; Collins, 1992) methodology was used to collect and analyze the data. The setting for the study was an independent urban school in a large diverse city in Canada. Twenty-two students in grade two (age 7 -8), their teacher, and two teaching assistants participated in the study. The students were representative of the city in terms of ethnicity, economic background and gender. The teacher and teaching assistants were new to Knowledge Building, digital storytelling, and the Knowledge Forum® software. The students had some experience with Knowledge Building but limited exposure to using computers and the Knowledge Forum software in school. The focus of the inquiry science portion of their curriculum was to study salmon in order to understand their entire life cycle as well as their habitat. This was in context of helping preserve salmon habitats in Canada. The class had a salmon tank that allowed them to observe salmon go through the first few stages of life before they could release them into the wild. To support student inquiry into salmon, they participated in offline Knowledge Building Circle discussions, textual and drawing idea input in Knowledge Forum, clay modeling of salmon stages, journal writing and sharing, and digital stories within Seesaw.

Knowledge Building sessions occurred twice a week for approximately 45 minutes each time. The study lasted 9 weeks. In the first- and second-week students were introduced to Knowledge Forum (KF) due to having little prior exposure. Also, in the second week a salmon eggs were brought into the class and put into the salmon tank. Third week introduced the students to KF's drawing tool so they could be familiar with using it to express their ideas beyond text. In the fourth week the students continued inserting notes regarding their understanding of the salmon life cycle with the goal of building on each other notes. In the fifth and sixth weeks, students began creating clay models that personified their understanding of salmon. Week seven and eight, students began salmon journals that sought to capture the knowledge they learned up to that point and their personal thoughts regarding the past few weeks of learning. These journals were meant to collect student understandings of their learnings over the past several weeks in order to produce a digital story in future weeks. It also gave them an opportunity to express their metacognitive thoughts regarding the various weekly learning activities. This would serve as a crucial step as it mimics script writing that is essential for digital stories. The last week of the study saw a complete switch of platforms due to the pandemic faced globally, resulting in all students, teachers and researchers having to work remotely together through the video conferencing software, Zoom® and online learning platform, Seesaw®. To consolidate all that had occurred in previous weeks, week nine saw all clay models captured and shared on Seesaw for students to create short audio notes on top of the image.

Data Analysis

There were a number of data types collected from this study in order answer the two research questions. Observations were collected each week, video and audio recordings from various Knowledge Building Circle and clay modelling sessions, analytical data from Seesaw and Knowledge Forum and lastly meeting and interview notes with the teacher. All videos and audio recordings were transcribed verbatim with grammar corrected. Analytical data collected from Knowledge Forum was used to compare various Knowledge Building session to observe potential improvements. Meetings and interview recordings and notes were transcribed verbatim to determine the success, shortcomings and areas of improvement for the integration of DS into Knowledge Building. In combination, all data were analyzed for common themes with the two research questions acting as guides.

Findings

After nine weeks of investigating the integration of DS practice into Knowledge Building a few key themes emerged based on weekly iterations to the lesson plan and activities. Through thematic analysis the following themes emerged: *multiple points of entry*, *authenticity of learning,* and *sharing leads to constant reflections*. Each of these emergent themes can be considered essential elements for enhancing student learning in Knowledge Building and beyond.

Multiple points of entry

From week-to-week, students moved from KB circles, to note writing in Knowledge Forum, using the drawing tool, and building clay models of salmon stages, journal writing and sharing and finally creating short digital stories in Seesaw. Each stage allowed for students to engage with their understanding of salmon in different ways as the medium shifted. Some stages were less productive than others due to the lack of points of entry for the student. In particular use of software that focuses largely on textual input or writing can limit a student's ability to express themselves. As an example, it was observed that students, although engaged and motivate by using a computer for learning, did not necessarily convey all they knew about the early stages of a salmon lifecycle. Most of their notes were simple and used a limited set of vocabulary. Conversely, the use of clay allowed students to physically manifest the depths of their understanding, beyond what they could articulate through words alone. Many students included fine details such as eyes on their salmon eggs as they saw them physically on the salmon eggs in their salmon tank or they gleaned the information from the variety salmon books in the classroom. One student for example when constructing the fry stage of a salmon also included an adult salmon for scale and reference.

In discussing the accessibility of DS, the teacher (personal communication, April 24, 2020) states that "the disconnect between generating and idea and having it come out as proper language on paper, it isn't fair for the kids as the purpose of inquiry is to develop their understanding, building and sharing knowledge". By limiting the means in which students are able to express what they know especially in the early stages of their development hinders not only their ability to share the entirety of what they know but also their motivation to participate. It was very apparent when the students started the journal writing activity they often rushed to finish and mostly through the copying of information from salmon textbooks. Many of the students subsequently did not want to share their journal entries. Comparatively, this speaks to how DS offers the flexibility of multimedia student input on any given subject. It allows students, teachers and researchers the ability to convey and capture a wider gamut of student subject knowledge and understanding.

Authenticity of learning

Although students were generally excited about studying salmon, especially with a live salmon to observe in the classroom, authentic or the genuine desire to learn was not always present. When there was a heavy emphasis on answering the question, such as during a few of the journal writing sessions contrived learning seemed to occur. Students ran back and forth between their notebooks and textbooks to gather information to complete the task. During times of clay modeling or recording audio notes in Seesaw a certain level of authenticity toward learning was apparent. For example, Student A remarked that they particularly enjoyed using clay to learn about salmon because “I had fun getting my hands all dirty”. Clay modeling was often accompanied by metadiscourse amongst students about their learning, and intentions as they were building. “You are learning not because you are told too, but because you are engaged” (D. Osorio, personal communication, April 24, 2020). This engagement with various mediums resulted in students being able to showcase the depth of their understanding. Student A was able to describe in detail stages of salmon growth and standout characteristics of the stages in his digital story. These stories about the creation of artifacts in clay, digital or otherwise leads to more authentic and engaged students as there is less emphasis on comparing if your theory is better than someone else’s.

In addition, it was very apparent the activities that engaged the students versus those that did not. Excited students had more metadiscourse or what I would call *creative exposition* regarding their work while unengaged students had minimal to say regarding what they were doing. *Creative exposition* is the act of talking through what you are thinking or doing with others while you are actively engaged in a creative endeavour. Authenticity was present in varying degrees over the weeks, however the most authentic moments of learning occurred where students were given a greater degree of *epistemological agency* and creativity to construct their understanding. As successful as Knowledge Building is at setting the stage for community-first and student led creative work with ideas this study found the addition of digital storytelling elements produced larger amounts of genuine interest in learning.

Sharing leads to constant reflections

Tsoukas’ (2009) states that new knowledge is created through a dialogical approach. Essentially through dialogue individuals go through a series of *conceptual combination, expansion* and *reframing* that leads to new knowledge being built and entered into the community’s lexicon of understanding toward a subject (Tsoukas, 2009). As students engaged in *Knowledge Building discourse*, it actively clarified concepts from a personal and community point of view. When sharing their journal entries with the class it highlighted a student’s unique learning journey but also caused others within the community to reflect on their own individual journeys. The conflict between what a student experienced and what they were hearing can lead to a deeper level of understanding of both the subject and their own learning.

An important distinction was made by the teacher and through observations of dialogical approach to Knowledge Building in the class and online. Sharing for the simple task of completing an assignment did not create genuine opportunities for deeper conversations or further genuine reflections by students. What motivated, engaged and excited students was the sharing of personal stories and perspectives. For example, one student shared their trials and tribulations with working on clay models of a salmon redd leading to something that resembled a shoe, which was met with joy, support and agreement. Even during the early weeks of the study where the focus was on writing notes in Knowledge Forum, many students would share their own micro stories about what they were doing which resulted in seemingly greater levels of discussions about the subject itself.

Discussions

The data suggests that in the incorporation of digital storytelling practices in a Knowledge Building framework can lead to consistent and frequent reflections regarding a student’s learning journey. The constant cycle of sharing and reflections can lead to both the deepening of knowledge and further sharing of personal stories as the students seek to validate their understanding in relation to others. When many students begin sharing and trying to co-construct meaning a dialogical approach (Tsoukas, 2009), they begin sustaining creative work with ideas (Scardamalia, 2002) in an authentic manner.

Furthermore, by working through a number of activities related to digital storytelling such as the building of artifacts that could fit into a final story, students often have *creative expositions*. These expositions are free flowing discussions that suggest student engagement with a particular learning activity. These discussions can be linked to Glaveanu (2018) concept of *creativity as a craft*, in which creative activities do not happen within a vacuum, but rather in the midst of a community; simultaneously influencing and being influenced by those around you. With increased interaction through sharing, students are able to build knowledge together rapidly and in a manner that is natural rather than contrived. Again, the observations highlight the potential for digital stories as the catalyst for heightening a student's motivation to learn, participate and become a valued member of a community.

In order to get students to a point in which they are ready to express themselves productively there needs to be multiple points of entry into the discourse. The study demonstrated a correlation between different types entries and their overall impact on a student's learning demeanour. Particularly at the grade two level, students were drawn toward creative activities in comparison to once that felt staged or explicitly required them to develop skills rather than engage with the subject matter.

Overall, the results indicate that when digital storytelling practices and activities are included as part of Knowledge Building, students are able to showcase the incredible depth of their subject matter understanding through different mediums. This is important as it highlights the need for different approaches to teaching and learning as well as the Knowledge Building pedagogy as it stands. Engaging students at a fundamental level in which they are willing to share in an uninhibited manner due to their excitement for a series of activities leads to greater sustained creative work ideas. Furthermore, it aids students in consistently sharing their insights, experiences and work which is beneficial for themselves and their peers. Below (see figure 1) I have illustrated a concept model for the integration of digital story practices in Knowledge Building.

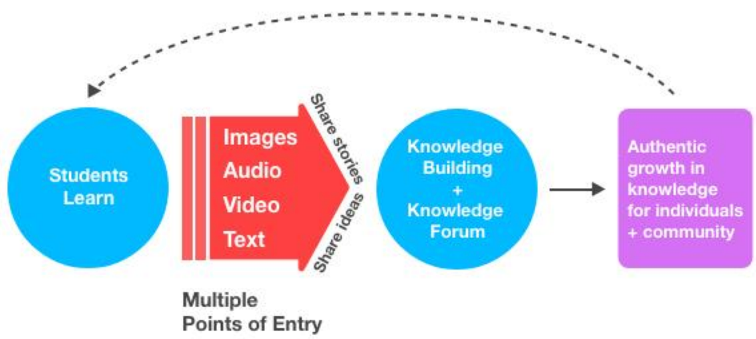

Figure 1: Emergent model of digital storytelling integration with Knowledge Building

Conclusion

This study aimed to investigate the integration of digital storytelling practice within a Knowledge Building pedagogical framework and determine its feasibility in sustaining creative work with ideas. Based on the analysis of qualitative data digital storytelling has a positive and lasting impact on students as it provided multiple ways for students to engage with the subject and more importantly the community. In addition, it highlighted the need to expand and develop tools within Knowledge Forum to enable digital storytelling activities. While these results positively position digital storytelling as a means to draw upon and sustain student creativity it also raises questions regarding the long-term effects on the development of skills necessary at a particular grade level as well as the potential it may have on the teachers pedagogical planning. Further research is needed in both areas to determine how storytelling can be included in Knowledge Building so that it is a seamless integral component of the pedagogy rather than an addendum. Lastly, it would be beneficial to attempt this study again with more than one class over a longer period of time to compare and contrast the results.

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Advancing Creative Drama Through Knowledge Building in Grade 5

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Abstract: This study applied Knowledge Building to creative drama in the teaching of Grade five in a primary school in China with 37 pupils. This research tracked the process of reading Harry Potter and the Sorcerer's Stone, over one semester. We collected artifacts of the Knowledge Building activities, including mind maps, scripts, rehearsals, formal performance and reflection. The results showed that: (1) the creative drama was constantly generating and evolving; (2) Knowledge Building enhanced students' reading and understanding.
Keywords: Knowledge Building, Creative Drama, Reading Comprehension.

Introduction

Creative drama is a process-centered and non-performance form of teaching based on a certain text. It is a dynamic process for participants to construct text information meaning, generate personal ideas, express experience feelings and exchange thoughts and feelings through role-playing and imagination experience (Jed H. Davis and Tom Behm, 1978). Not used to entertain people, creative drama is used as an instructional means to improve children's learning ability and critical thinking ability (Zhang, X.H., 2004). Previous studies have proved that creative drama can promote students' deep processing of text (Shepard, 1992), can deepen students' memory and understanding of text-processing skills (Anderson, 1990), and stimulate children's initiatives(Choi, Kyoung, 2011). Luo, W. N. et al (2019) believe that there is a transformation between imitation and innovation, between individuals and groups, and between performers and viewers.

In the previous research, creative drama was mainly applied in kindergarten education, mainly "play" games or activities, most of which are topics or stories arranged by teachers, with certain flow procedures. As one of the third metaphors of knowledge creation, Knowledge Building is a principle-based pedagogy (Scardamalia, 2002; Scardamalia & Bereiter, 2010) that aims to promote students' idea improvement through sustained discourse. In the process, community knowledge is co-constructed (Hong & Sullivan, 2009; Zhang et al., 2011) or artifacts are formed. Knowledge Building has proved to support the development of students' higher-level reading comprehension (Lin P.Y. & Hong H.Y., 2019) and to be positively related with reading skills (Zhang, & Sun, 2011).

The research untaken herein tracked the process of reading Harry Potter and the Sorcerer's Stone in a fifth grade class. It mainly analyzed the Knowledge Building process of script writing, rehearsals, formal performances and reflection. This study focused on the research questions: (1) How does the creative drama emerge in the process of Knowledge Building? (2) Will the Creative Drama improve students' reading comprehension?

Methods

Participants

The participants in the study were 37 pupils of a Grade 5 class, from Xinjiang Province of China. They have been taught by Knowledge Building instruction for 2 years and had read the novel of “Journey to the West” using the creative drama teaching method before. They were active and interested in projects and activities.

The teacher is an expert teacher, with 10-year teaching experience and has carried out reading reform of Knowledge Building for 4 years.

Pedagogical Design

Knowledge Building was adapted in the creative drama of Harry Potter and the Sorcerer's Stone, lasting for one semester which reflected the principles of the real ideas, epistemic agency and rise-above. The creative drama process was divided into four phases according to Knowledge Building discourse (Lossman, 2010): autonomous reading and theme generation, group formation and script writing, role generation and drama performance, reading promotion and theoretical building, which reflects the generation and evolution of creative drama.

(1) Autonomous reading and theme generation: One of the principles of Knowledge Building is the real ideas and the real situations. Firstly, students read "Harry Potter and the Sorcerer's Stone" independently during the summer holiday. Then in Grade 5 they put forward individual questions which they were interested in through the knowledge building activities. Diverse ideas were discussed with classmates in the reading exchange class. Different themes were formed, such as the theme of people, magic biology, magic objects, magic spells, etc. The students communicated with the classmates twice a week through Knowledge Building Circle, lasting for one month.

(2) Script writing and group formation: One principle of Knowledge Building was that students were epistemic agency. In the creative drama, the group was gradually formed spontaneously with the continuous inquiry of themes. After one month reading, students began to write and modify scripts.

(3) Role generation and drama performance: The roles of the director and actors were generated by the students themselves. Screenplay rehearsals and performances are the most interesting, the most engaged, the most dynamic for the students. There were 3 rehearsals in the open playground.

(4) Reading promotion and theoretical building: Students transcended the trivial and simple discussion so that the Knowledge Building could reach a higher level. So students wrote reflection after the creative drama performance. Every student wrote their ideas about drama, performance, the Knowledge Building process and so on.

Data sources

Data were collected from student artifacts, including posters, scripts and reflective diaries. Students modified every artifact several times and submitted the final artifacts (see Table 1).

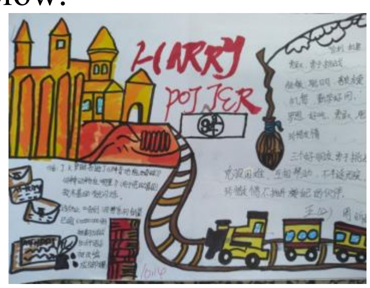
Table 1: Students artifacts.

Items	Number	Amount
Mind mapper	29	
Script	7	6800 words
Performance	7	32 min
Summary	37	14800 words
Reflection	37	14300 words

Results

The creative drama was constantly generating and evolving

The greatest characteristic of creative drama under the Knowledge Building environment was generative. The creative drama was spontaneously generated, including the themes, the roles and the performance. Each phase produced different artifacts, which fully reflect the generation of creative drama. Some of the artifacts were shown below.



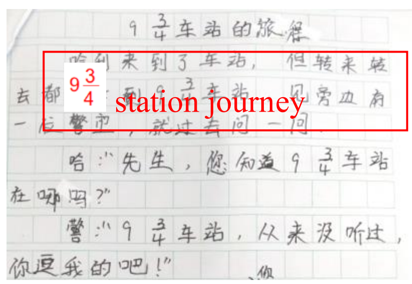


Figure 1. Students' Mind Map. Figure 2. Students' Script.

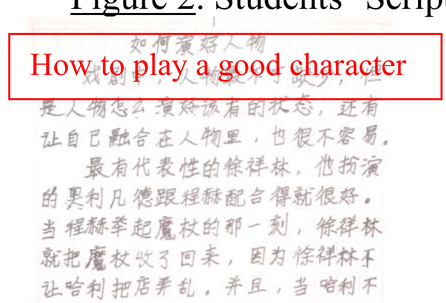


Figure 3. Performance of the Creative Drama. Figure 4. Students' Reflection.

Themes generating: Students became interested in different people and goods, such as Harry Potter, the Sorcerer's Stone and so on, when they read the books. Then they studied them such as the life of Voldemort, why it become a big devil and drew some mind maps. The same or similar interest merged into a theme and the themes formed.

Scripts evolving: There might be conflicts between ideas and they learned to negotiate with others, established links between ideas, and developed their ideas continually. At first, everyone wrote a drama, including 37 dramas with 11 themes. Then 7 dramas were voted to be rehearsed. Everyone could join the themes and formed research groups to modify the scripts together. The final 7 dramas were: wands, nine and three-quarters stations, yard caps, magic medicine classes, midnight duels, demon nets and double-faced men.

Roles generating: The director could be the screenwriter or be voted by the members. The actors could be selected more flexibly, 2 groups were optional roles, 4 groups were assigned by the director according the members' characteristics, 1 group is recommended by members.

Performance evolving: There were 3 rehearsals, each 45 minutes, in the open playground. Three students volunteered as presenters. The students enjoyed the joy of the play.

Theory building: As one of the metaphors of knowledge creation, Knowledge Building emphasized the sublimation and rise-above of ideas. Idea improvement and theory building were the characteristic of Knowledge Building which was the difference with other inquiry activities. For example, Why to perform the drama? How to perform a script? How to be a good actor? How to prepare props? How to relax before you get on stage? What are the characteristics of drama? and so on.

Knowledge Building enhanced students' reading and understanding

Students transformed from reading to creating through Knowledge Building. They read the novel, presented their own understanding in various artifacts and tried to write, rewrite and even create plots. Under the guidance of the teacher, students wrote summaries and reflections, which were much better than propositional composition, with both true feelings and sparks. Through sublimation, the students put forward more complex ideas. In the end the reading and understanding ability improved rapidly which was reflected in the final scores of the exam. The average score of the three classes was 87.7 in Chinese. The experimental class(class 2) was 88.9 which was the highest score among the 3 classes compared with the previous equal average (see Table 2).

Table 2: Students scores.

Class	Num	Min	Max	Mean±SD
Class 1	35	46.0	98.0	86.4±9.97
Class 2	37	46.0	97.5	88.9±9.74
Class 3	37	70.5	96.5	87.7±6.63

Discussion and future directions

In this study, we examined Knowledge Building activities and creative drama improvement of Grade 5 in a Chinese class. The creative drama was developing and evolving under the Knowledge Building theory with the use of discussion, scaffolds, Knowledge Building circles, Knowledge Building walls and so on. From the initial spontaneous interest to scripts, rehearsals and so on, it fully reflected the generation and evolution process of creative drama, which was the biggest difference from other activities with fixed procedures. Under the guidance of Knowledge Building, students summarized and reflected to continually rise above their ideas. In the process, students read books actively and expressed their understanding in various artifacts. Finally, they improved the reading comprehension distinctly.

As for the learning platform, this creative drama mainly used face-to-face communication without the application of Knowledge Forum because of habits. In subsequent classes, we will try to apply Knowledge Forum in primary school in order to visualize the students notes and discussion for deeper analysis.

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The Structure of Knowledge Building for Promising Ideas in the Palliative Care eLearning Program

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Abstract: The Palliative Care eLearning Program is a continuing professional development program for family physicians and nurse practitioners. This program builds on the 10-year success of the End-of-Life Care Distance Education program that employed previous versions of Knowledge Forum. The current, non-linear, graphic display of KF6 notes is innovative and reflects the theory of Knowledge Building putting ideas-at-the-centre; however, it can become challenging for participants in an extremely active KF view. This is the design problem discussed in this paper. In response to high levels of discourse, i.e. note creation (n=577) and build-on activity, the design researcher created *views-within-a-view* that organized discourse according to case-based content. This solution was functional but created unwanted organizational structures segregating ideas, as opposed to integrating them in the same problem space and keeping them fluid and available for creative knowledge work. The inherent limitations of structuring space for Knowledge Building is contrary to its theoretical underpinnings. From this design researcher's experience with knowledge visualization, an expandable, easily navigable, 3D problem space is suggested for future KF design, beyond pages and views. KF as a 3D problem space could impact collaborative interactions and possibilities for work with promising ideas to further scaffold creative Knowledge Building.

Introduction

The Palliative Care eLearning (PCeL) Program, is an online continuing professional development program, for family physicians and nurse practitioners sponsored by the Ontario Ministry of Health and Long-Term Care (Figure 1), https://pcelprogram.ca. It was designed, developed, and is co-ordinated by Prof. Leila Lax and Dr. Anita Singh. It is supported by the University of Toronto, Faculty of Medicine, Office of Continuing Professional Development and certified by the College of Family Physicians of Canada for 211.5 Mainpro+ credits.

Figure 1. The Palliative Care eLearning Program homepage.

The PCeL Program 2019-2020 opened on Nov. 17, 2019 and was scheduled to run to May 6, 2020 but due to the current pandemic was extended until Aug. 26, 2020. There were 2 in-person sessions; the opening session, on Nov. 17, provided an overview of the PCeL Website, KF, Knowledge Building and an introductory lecture on palliative care and the March 7 session provided a lecture on palliative symptoms and small group case-based discussion. All 6 modules were conducted online with participants working seamlessly between the Website, individual, knowledge translation (KT) assessment components and Knowledge Forum (KF) for collaborative, case-based discussion to support Knowledge Building for new knowledge and improvements in practice. Participants' 12-week post-program KT to practice journals are due online on Nov. 18, 2020.

The pedagogic model is a novel blended design, created with a competency-based architecture, combining individual, asynchronous elearning focussed on KT formative feedback assessments (Lax, Singh, Scardamalia, et al., 2006, 2015; Lax, Scardamalia, Watt-Watson, et al., 2010) with collaborative Knowledge Building in KF (Bereiter & Scardamalia, 2003, 2014; Scardamalia, 2002; Scardamalia & Bereiter, 2014; Lax, Philip, Singh, et al., 2016), as well as, 2 synchronous, in-person sessions. The formative feedback assessments, called KT Exercises, are based on 10 palliative care core competencies, defined by detailed milestones and associated with CanMEDS roles and family medicine principles (Fig. 2).

The KT Exercise pre/posttest knowledge scorecards are structured by these competencies/milestones to inform self-assessment, guide individual KT Plans, and elevate collaborative Knowledge Building discourse. Each module begins with a list of case related competencies/milestones. At the conclusion of each module, after 4-weeks of KF discourse and review of eLibrary resources, participants are asked to rate their level of proficiency with each module milestone, reflect, and create a KT Plan of action for continued improvement. All authoritative resources in the eLibrary are also linked to competencies/milestones. The cumulative KT Plan leading to the PCeL Journal requires 12-week follow-up through action, evidence, and reflection on 2 self-selected practice priorities.

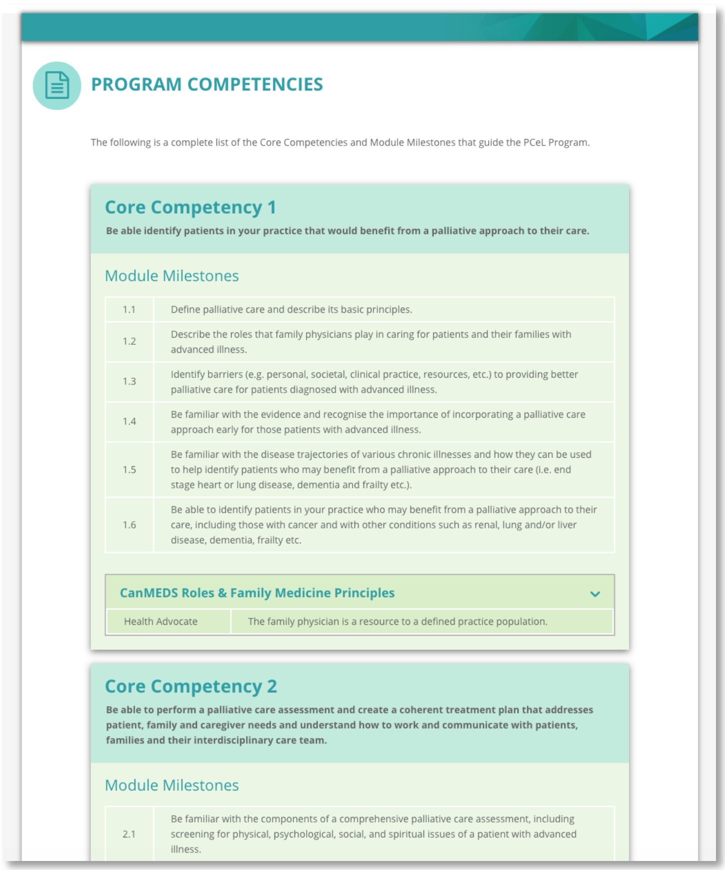

Figure 2. Core competencies and module milestones related to CanMEDS roles and family medicine principles.

Access to KF is embedded in the PCeL Program graphic index on the top menu bar and within each module (Figs. 3 & 4). The design of the PCeL Program graphic index is reflected in KF; all 6 modules are designated as separate views based on the case-based content of each module/view (Fig. 5). A detailed schedule is provided in each module for participants' asynchronous individual and collaborative work over the course of 4-5 weeks per module (Fig. 6). Collaborative Knowledge Building in KF is scheduled for 27 weeks, followed by the 12-week post-program KT Journal that prompts participants to take action on new knowledge to elevate personal practice, provide evidence of change, and reflect on the impact; the Journal is the final component submitted online for calculation of individual Mainpro+ continuing professional development credits. All components of the PCeL Program are aimed at scaffolding participants to go beyond elearning – to do Knowledge Building work not just to obtain additional knowledge but potentially to create new knowledge and translate knowledge to practice, to evoke change, and improving one's care of their palliative patients and their families.

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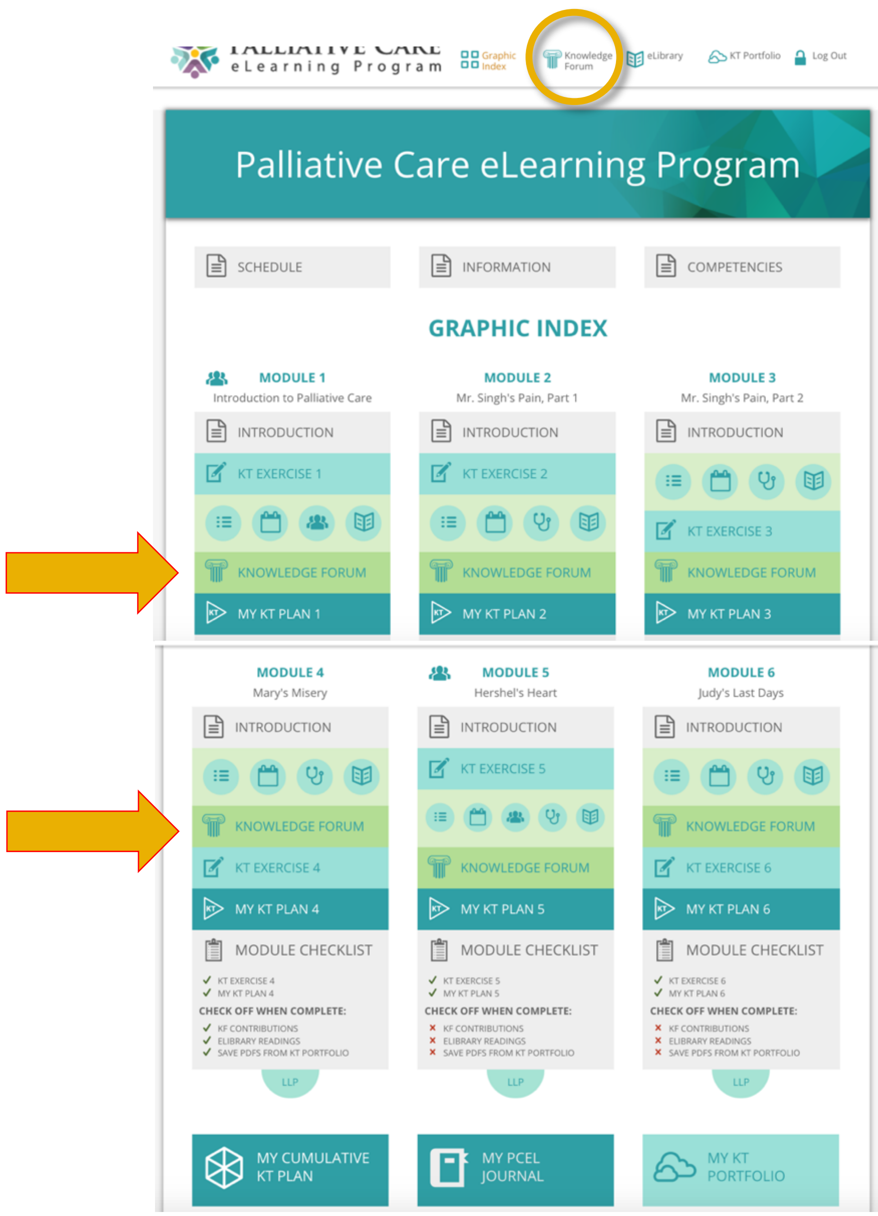

Figure 3. Knowledge Forum is embedded in the PCeL Program graphic index & all modules.

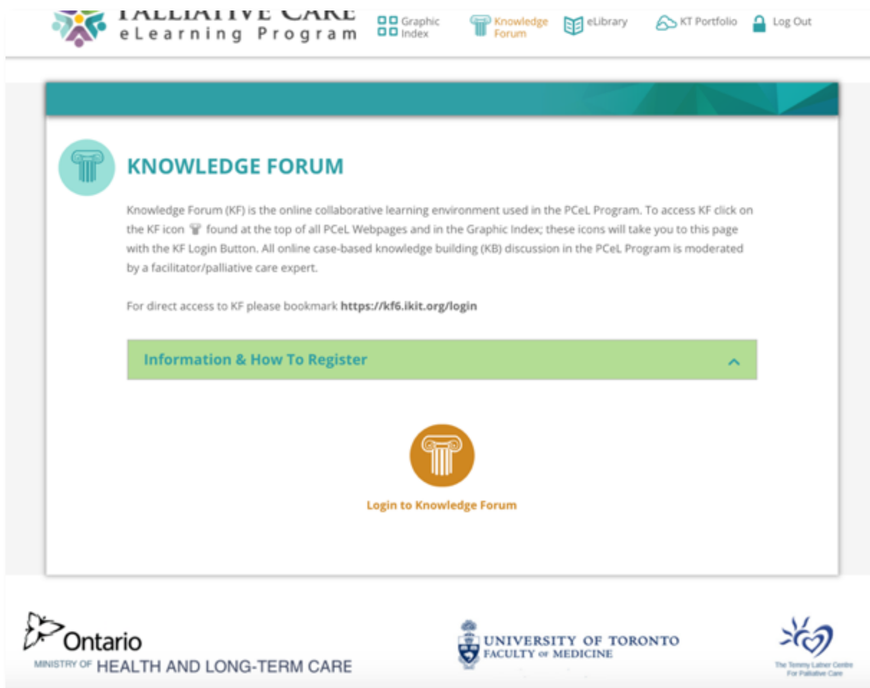

Figure 4. Access to Knowledge Forum login is seamlessly integrated.

Figure 5. The 6 module design of the PCeL Website is reflected in Knowledge Forum.

Figure 6. A sample module schedule, across 5 weeks, detailing participant responsibilities.

Participants & Methods

The educational research component of the PCeL Program was approved by the University of Toronto Social Sciences Research Ethics Board. The PCeL Program 2019-2020 was fully registered with 22 family medicine participants. In April 2020, during COVID-19, participants were asked if they would like to end early and receive partial Mainpro credits. Thirteen participants completed the 2019-2020 program. Two facilitators, experts in palliative care, guided the discourse in KF – one for modules 1, 2, and 3 and the other for modules 4, 5, and 6. KF analytic tools were employed for activity statistics and an online survey was conducted for formative feedback and program evaluation.

Results

Knowledge Building activity: Number of notes read and number of notes created for each participant were tabulated in KF. Total online activity across 6 modules showed 11,052 notes read minus 811 (by the design researcher) for a subtotal of 10,241 and a total of 641 notes created minus 64 (created by the design researcher) for a subtotal of 577 (Table 1). The KF ideas building tool was employed to provide an image based on data from build-on notes in Module 2, embedded view for ideas-at-the-centre of pain assessment and management; it shows a high level of interaction, not only by the facilitator (largest circle) but by numerous participants (medium size circles) (Fig. 7).

Table 1. Knowledge Forum participant activity summary

	Number of Notes Read	**Number of Notes Created**
Participants (n=22)	9289	499
Facilitator 1	452	44
Facilitator 2	500	34
Subtotal (Ps & Fs)	**10241**	**577**
KF Views (DR)	811	64
Total	11052	641

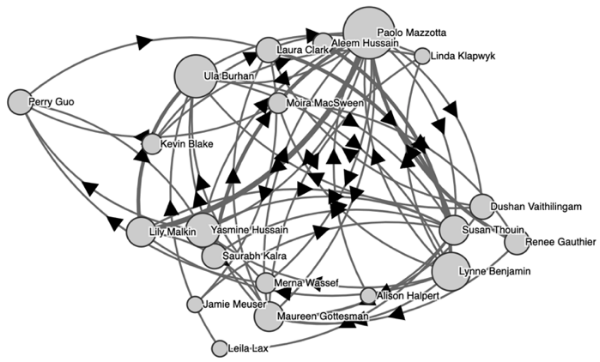

Figure 7. Ideas building (build-on contributions) from module 2, pain assessment & management view.

Program evaluation survey: An online survey in Survey Monkey was conducted at the conclusion of the program for formative feedback and program evaluation as required by Continuing Professional Development, Faculty of Medicine, University of Toronto. Eight responses were received (from a possible 13 participants that completed the program). The survey was composed of 3 demographic questions, 10 Likert-scale (strongly disagree to strongly agree) program feedback questions, a series of Likert-scale (novice to expert) outcomes self-assessment questions, 4 KT feedback questions and 3 final feedback qualitative response questions. Overall the PCeL Program was very highly rated across different aspects (Table 2), as were the palliative care cases, discussion in KF, and Knowledge Building components (Table 3). Quantitative and qualitative responses to KT impact on practice are notable (Tables 4 & 5). All CanMEDs roles were well represented, except "Leader" (Table 6).

Table 2. PCeL Program ratings of face-to-face sessions, eLearning website & Knowledge Forum.

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	TOTAL	WEIGHTED AVERAGE
The face-to-face session facilities were satisfactory.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
The PCeL Program Website was satisfactory.	0.00% 0	0.00% 0	12.50% 1	37.50% 3	50.00% 4	8	4.38
The Knowledge Forum discussion environment was satisfactory.	0.00% 0	0.00% 0	12.50% 1	50.00% 4	37.50% 3	8	4.25
Overall, the program content enhanced my knowledge.	0.00% 0	0.00% 0	12.50% 1	50.00% 4	37.50% 3	8	4.25
Overall, I would rate the face-to-face sessions as excellent.	0.00% 0	0.00% 0	0.00% 0	62.50% 5	37.50% 3	8	4.38
Overall, I would rate the PCeL Program as excellent.	0.00% 0	0.00% 0	12.50% 1	25.00% 2	62.50% 5	8	4.50

Table 3. PCeL Program feedback on cases, Knowledge Building & authoritative resources.

Strongly Disagree Disagree Neutral Agree Strongly Agree

	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	TOTAL	WEIGHTED AVERAGE
The cases used in the in-person seminars were interesting.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
The online cases were interesting.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
The online cases promoted discussion in KF.	0.00% 0	0.00% 0	0.00% 0	57.14% 4	42.86% 3	7	4.43
The ideas-at-the-centre helped to promote KF discussion.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
I gained new knowledge from the online discussions.	0.00% 0	12.50% 1	0.00% 0	37.50% 3	50.00% 4	8	4.25
I had the opportunity to ask questions about my personal practice in the online forum.	0.00% 0	0.00% 0	0.00% 0	62.50% 5	37.50% 3	8	4.38
The eLibrary references were easy to access.	0.00% 0	0.00% 0	0.00% 0	37.50% 3	62.50% 5	8	4.63

Table 4. PCeL Program rating of knowledge translation to practice.

Strongly Disagree Disagree Neutral Agree Strongly Agree

The KT Exercises/Pretests & Post-tests were challenging.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
The KT Pre-tests & Post-tests Scorecards were helpful to me.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
Scorecards provided helpful self-assessment feedback by milestone/competency.	0.00% 0	0.00% 0	0.00% 0	50.00% 4	50.00% 4	8	4.50
Developing KT Plans were helpful to me.	14.29% 1	0.00% 0	14.29% 1	42.86% 3	28.57% 2	7	3.71
Creating a Cumulative KT Plan, identifying 2 Practice Priorities, was helpful to me.	12.50% 1	0.00% 0	25.00% 2	50.00% 4	12.50% 1	8	3.50
I am looking forward to working on my 2 Practice Priorities and documenting this in the 12-Week Knowledge Translation to Practice (KTP) Journal.	12.50% 1	12.50% 1	25.00% 2	50.00% 4	0.00% 0	8	3.13
Having an online assessment Portfolio was helpful to me.	0.00% 0	0.00% 0	25.00% 2	75.00% 6	0.00% 0	8	3.75

Table 5. PCeL Program feedback on knowledge translation to practice.

Q14. What will you do differently in your practice as a result of this program?

#	RESPONSES	DATE
1	approach to symptom management grew	9/3/2020 12:02 PM
2	Use ESAS for describing symptoms. Better manage non-cancer palliative patients	9/2/2020 9:33 PM
3	Knowing community tools that are available in the community	9/2/2020 8:55 PM
4	Continue applying strategies in practice	9/2/2020 8:49 PM
5	mentally screen patients for palliative support/needs talk about ACP more take on more symx management	8/25/2020 2:34 PM
6	Better assessments, more collaboration, earlier discussion re patient preferences	8/21/2020 6:04 PM

Table 6. PCeL Program rating of applied CanMEDs roles.

ANSWER CHOICES	RESPONSES	
Family Medicine Expert	75.00%	6
Communicator	87.50%	7
Collaborator	75.00%	6
Leader	25.00%	2
Health Advocate	75.00%	6
Scholar	50.00%	4
Professional	62.50%	5
Total Respondents: 8		

Discussion

Strong Knowledge Building activity and survey results from the Palliative Care eLearning Program 2019-2020 provide initial, overall positive feedback on design. Feedback on the post-program Journal was conducted in advance and it is recommended that in the future feedback should be obtained after Journal completion to gage impact on practice. A notable design issue in KF persists related to very high levels of note creation and build-on notes.

Design problem**:** The PCeL Program employs KF6 and builds on the 10-year success of the End-of-Life Care Distance Education Program using previous versions of KF. The non-linear, graphic display of KF6 notes is innovative and reflects the theory of Knowledge Building putting ideas-at-the-centre; however, it can become challenging for participants in an extremely active KF view (Fig. 8). This design problem is an issue that we continue to address in this program. In response to high levels of KF discourse, i.e. note creation and build-on activity, in PCeL 2018-2019, the facilitator created "rise aboves" and then the design researcher created *views-within-a-view* to organize discourse according to case-based content and ideas-at-the-centre in the PCeL Program 2019-2020 (Fig. 9-13). The *views-within-a-view* solution was functional but created unwanted organizational structures segregating ideas, as opposed to integrating them in the same problem space and keeping them fluid and available for creative knowledge work. The inherent limitations of structuring space for Knowledge Building is contrary to its theoretical underpinnings.

Design possibilities**:** Inspired by other work in 3D knowledge visualization and interactivity design (Miller, Lax, Wooldridge, et al., 2018; Gautier & Jenkinson, 2018) the design researcher envisions an expandable, easily navigable, 3D problem space, that goes beyond the current design of 2D pages and KF views. Re-designing the KF problem space could impact collaborative knowledge work, interactions with ideas, and possibilities for identification and work with promising ideas (Chen, 2017) to better facilitate "rise-above" progressive discourse and scaffold higher-levels of creative Knowledge Building (Scardamalia, 2002; Scardamalia & Bereiter, 2014; Bereiter & Scardamalia, 2014). Promisingness and idea improvement may be better supported by a 3D, interactive, landscape design of notes within a KF view.

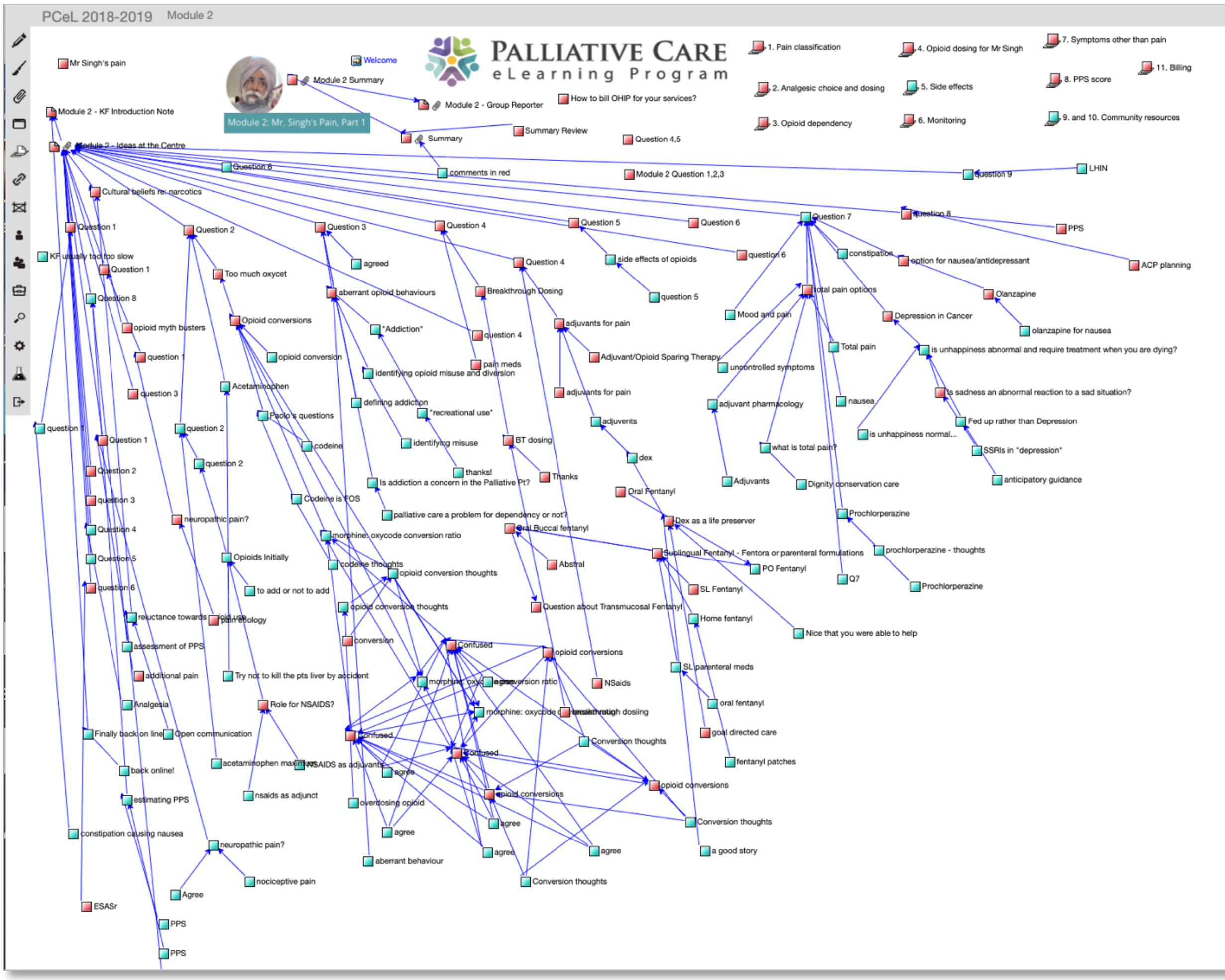

Figure 8. PCeL Program 2018-2019, module 2, KF view.

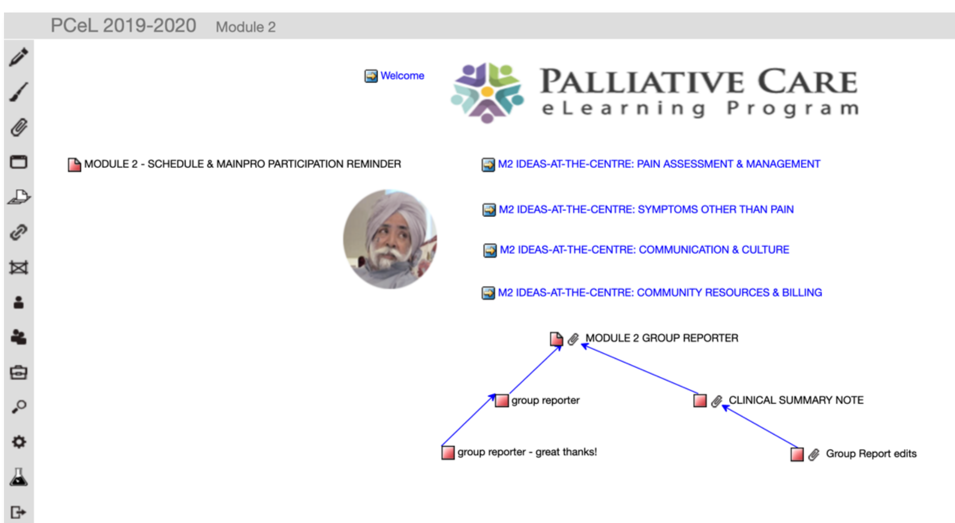

Figure 9. PCeL Program 2019-2020, module 2, KF view.

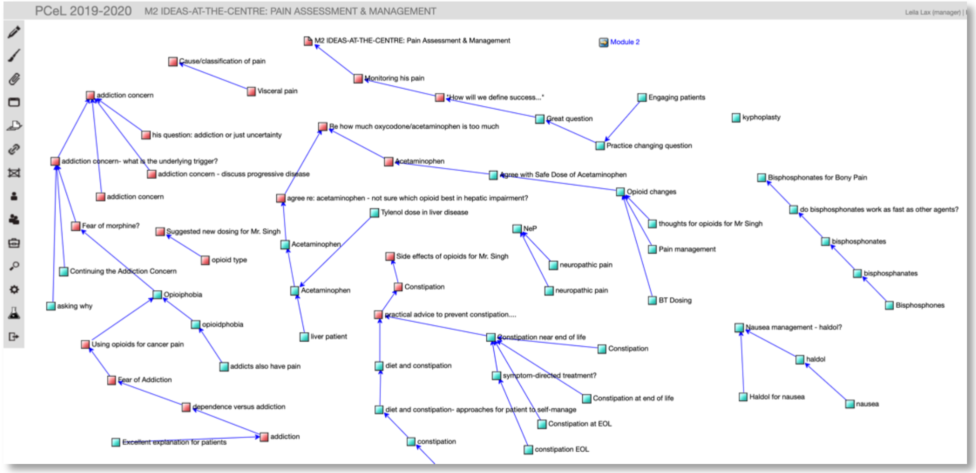

Figure 10. PCeL Program 2019-2020, module 2, Pain Assessment & Management, KF view (number of notes read=1483; number of notes created=68).

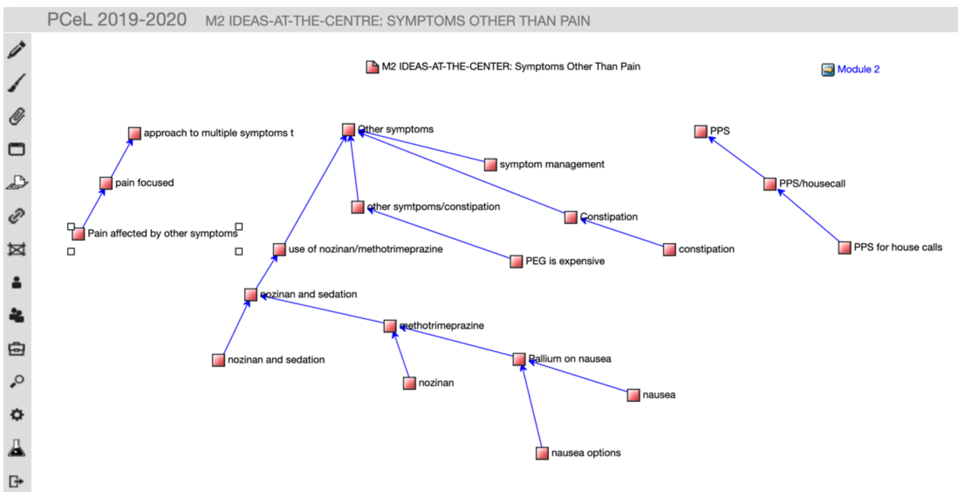

Figure 11. PCeL Program 2019-2020, module 2, Symptoms Other Than Pain, KF view (number of notes read=430; number of notes created=21).

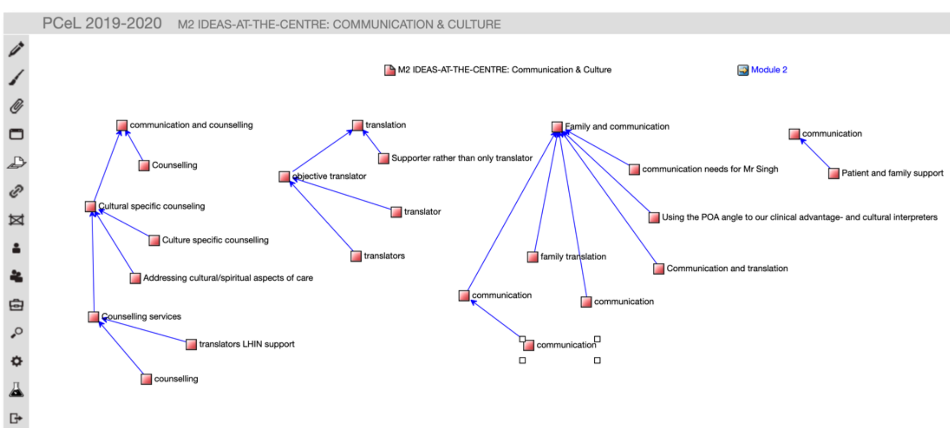

Figure 12. PCeL Program 2019-2020, module 2, Communication & Culture, KF view (number of notes read=438; number of notes created=24).

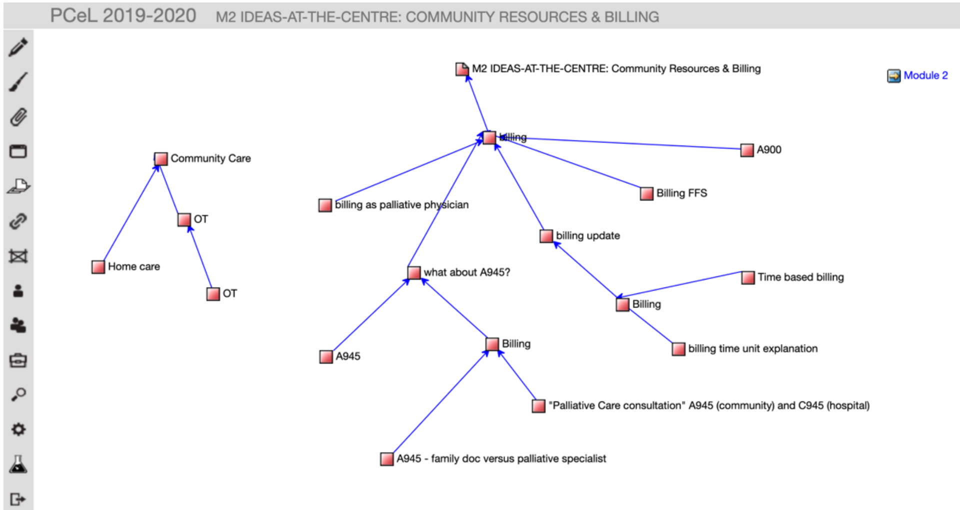

Figure 13. PCeL Program 2019-2020, Module 2, Community Resources & Billing KF view (number of notes read=344; number of notes created=18).

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Open Up an Account Ability Gap for Real Learning

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Abstract: Education is about embracing productive social experience in the present, just as preparing for roles in the future. For schooling to be re-conceptualised to realise the potential of Knowledge Building requires a rethink in the nature and function of audit and accountability. My analysis is framed in the mismatch between audit, pedagogy and assessment in school reforms in Scotland. A new national approach from 2004 was centred on fostering capacities of potential, expressly building approaches at school level. I found that audit has a lot of unlearning to do to assist and be part of such approaches. Those in audit roles, individually and institutionally, require to engage respectfully with conceptual and theoretical realms formed within school communities. I urge that external audit now work with us in schools, practically and conceptually, to link components of our systems, enabling them to cohere and serve purpose – ours, not theirs. I identify an account ability gap wherein audit is not set up to give an account of itself. I seek that accountability enter into a design experiment within and as part of schooling integral to the unprecedented social and technological changes now occurring and in which schooling is ever more formatively embedded.

Talk

For nearly a decade and a half from 2001 I was the class-committed principal of a small rural primary school in Scotland. Being devolved for education in the UK, the then Scottish Executive and its curriculum agency, Learning and Teaching Scotland, brought in a new curriculum framework from 2004. Its central purpose was to foster children's potential as four capacities of responsibility, confidence, contribution and learning. These capacities were set in layered conceptual and operational components. This was an expressly transformational national endeavour. The capacities were framed as embodiments of potential centred on personal development, awareness and capability. It was a major shift from the hitherto focus on targetised attainment. Learning became part of something bigger – more intrinsic, more purposive, more relevant, more connected. This was a bold redirection of expressed goals for a national school education system. The initiative came about following a two-year national conversation of educators and all communities of interest. The incoming framework linked changing modes of consciousness arising through new digital media, assessment for learning, global citizenship, re-localisation, and new forms of collaborative learning, amongst much else.

To bring the endeavour to life we were asked to 'build the curriculum' – a collegiate developmental strategy of that name. This was not simply another initiative. The task was to reframe purpose and transform practice to it. We were asked to build this philosophy in our schools within the nationally agreed framework. It was not about prescription, and certainly not about imposed procedures. This was about re-visioning education. We were asked to make all this work for us in our locales, fashioned according to our context and needs. This was the basis of school education policy in Scotland for the twelve years to January 2016 when it underwent major alteration.

In Plockton Primary School we were enthusiastic exponents of the 2004-16 review principles and the central four-capacities approach. We opened up new opportunities through new technological potentialities and community linked approaches, but what was really new was the thinking. It was about intrinsic meaning in learning. It was about being. This new approach to education was to dispose the mind to think in new ways, to open up new potential through new means, technological and social. It was not about performance, or delivery or targets or tracking. It was about purpose. It was about ownership. We embraced these broad goals, working with the national curriculum agency, our local authority employer and national education department on collaborative action research projects, some of which we competitively bid for and were awarded. We worked with partners near and far. Our practice formed case studies of external bodies. I only touch on what we undertook, what altered, what successes and difficulties we encountered and what we achieved. Of central importance is what this all meant at the individual pupil/student level.

Our goal was that the pupils/students become the owners of these tasks and of the purposes wherein they lay. This is a higher order understanding of learning, developing oneself in collaborative interchange. We made major wholescale changes to our planning, development, assessment and organisational procedures and frameworks in accordance with the new national endeavour.

However, there was one problem my colleagues and I could not overcome. It was the misalignment of approaches and determinations of external inspection and its local authority bedfellow 'quality assurance,' pertaining to theoretical constructs, methodology and data integrity. These audits imposed judgements as imposed text and grades to pre-existing grade descriptors. But they did not make sense in the context of the then current reforms. Nor was there transparent articulation of data, method, analysis and substantiation.

I was in an out-of-school role from 2013. This gave me the opportunity to enter into a reflective and analytical mode as to our school achievements, and the nature of their transformation, concerning what was going on in our national system, and beyond. I analysed these, based on practice and development, wrote these thoughts up and presented on them, worldwide. I came to reflect on my role as the local lead manager, and also practitioner with a more than three-quarters full-time teaching commitment 2001 to mid-2012. I came to understand the promoters and inhibitors of system change. I came to the realisation that our audit agencies were opposed to the curriculum framework because they were misaligned to its conceptual rationale and hence their procedures and practices followed suit. In some of their documentation this is even explicit. I found there to be concomitant ethical issues. I presented at international congresses on Scotland's central four capacities reform throughout the world. As I did in Chile, Indonesia, the US, Canada, Singapore, Norway and Morocco so did they. But what they and I presented was entirely contradictory, yet based on the same national system. Note that I was presenting on enacted policy of over a decade to national guidelines from my stance as teacher practitioner and school principal.

My challenge to you here that I would like to share with you is how to deal with the mismatch between audit and curriculum. The challenge lies in shifting underlying concepts and assumptions to address essential questions, such as: What form of curriculum? (Not just as content). What form of audit? To what purpose? And for what lived reality on the way there?

Education is very much about the journey (as being – the lived experience) not only the end point (outcome as 'results'). Evaluation is (should be) about evidential engagement to enable learning disposing to action to optimise function to achieve purpose. It is not an act of judgement. It is about meaning and understanding to serve need and enable potential. Distil purpose. Generate meaning. Seek data. Garner insight. Generate knowledge. Adjust. Investigate. Learn. Reflect. Then stop. Smile. Look about. Be. And carry on.

I loved my job. We had a great time, but then we had a terrible time. Only slowly did I come to understand why. We had a terrible time *because* we were having a great time. We were getting somewhere, achieving something original, going somewhere new but in an audit, policy, reform and external accountability world which was not. There came to be a fundamental conceptual mismatch. Our curriculum agency did one thing, and our audit agency did another. We were pulled in two directions. I came to see that this is about institutional power. The problem is that the modes of thought are determined by audit. Instead they should be determined by purpose, derived from needs and potentials enabled through organisational means, and realised in practice, altering iteratively. What is needed is to reframe audit, with integral understanding, by bringing schools and their communities into the process as partners. It may then be possible to re-humanise audit and transform it to build organisational knowledge. I seek a change towards this mode of thinking and practice right across our system, and beyond. Productive purposive change in school education is not possible without it.

For me personally, I would wish to be enabled to do my job in a remote little school in the far North-West seaboard of Europe, but the contradictions rendered it impossible. It is the challenge I pose to you here, which I seek the wisdom of the crowd to solve.

Can we make external governance, accountability and reform serve our needs as school communities, rather than we serve theirs? Can we make school communities the agents of education system change? Can we turn we and they into us working together? I think we can! That is why I am here. We need a re-humanised school education system, and meta-system.

To do that we need to reframe our thinking. We have some unlearning to do first. We need to unpack accountability, turn it inside out, break it apart, and then re-form it, which is the true meaning of reform. Is accountability *able* to give an *account* of itself and so itself become *account able?* Mind the gap between the two words which is that of real learning and is where our humanity resides. We must rediscover the relationship between the parts in our immense school systems. They need to work together, as systems, not as fractured components.

This is where audit relates to the design experiment overview of this Knowledge Building Institute. Just as we as educators need new analytic tools to relate to rapidly altering pedagogies addressing new and rapidly altering societal needs, so do those who relate to us. As education moves ever more out of the classroom, literally and virtually, becoming more intrinsic and embedded in society, not just preparing 'learners' for future life roles but enabling them to enter into them within education settings, so the process becomes ever more collaborative, building knowledge, as students enter into design mode as part of their school life. This is even in younger age groups.

Society, through various institutions and communities of interest, including government, funding agencies, communities and parents seek means of engagement in the processes we enable in schools, and other education institutions. They have a right of involvement but also in new forms of engagement which echo the changes underway in education practice. Thus as education moves to and as a design experiment so do and must the forms of accounting, by which I mean how we give and receive accounts, constructing understanding and meaning as intrinsic accountability. Thus there is a need for accountability to enter into design mode. Its altering forms, serving very different needs, need to become an iterative experiment, integral to the functions, roles and purposes of our education institutions and the individuals within them, in all roles. Accountability, and all its bedfellows – audit, inspection, quality review, regulation, evaluation and so on – having subtle different nuances, need to become learning processes in themselves. They are processes steered by individuals, and those persons may shift roles, as we educators, and indeed students may become partners in, and indeed agents of accountability. Accountability as a process may then become built in and integral. It may come to function as a system and within the greater systems which it serves and of which it is a part. I wrote my 2011 paper as a class-committed school principal to provide a penetrative critique of difficulties and obstacles at the systemic level which were hindering my job function, and that of my colleagues, within Scotland's school education reforms and as they related to our societal context which is global. The paper also opened up a critique through conceptual and theoretical elaboration. It also outlined what was working well and why and how we may give an *account* of that, how and according to whose agenda. My point is that there are choices and they serve purposes as relate to needs and potentials. There is no one right way of audit and accountability. The presentations and papers of mine cited here formed the basis of this overview talk which represents the continuing evolution of the process, as does my involvement in the Knowledge Building community. All those with whom I and colleagues liaised and collaborated form a conduit through this. Accountability needs to become an enabler, from now into the future, not a disabler, as recently up to now.

So what can I, those who come after me in my job and role and those steering our local, regional and national system do about all this? Telling us what to do in schools is not the answer. But nor should we be left alone. We need to build relationships of all kinds at all levels which are mutual and constructive. With regard to accountability how may we reframe practices and assumptions about the linkage of audit and pedagogy? Can account ability replace accountability? Can we all become *account able* in holistic, meaningful, purposive and constructive interrelationships replacing destructive, one-way, one-sided accountability? Can we construct a design experiment of, and as, accountability? Are there solutions out there? Let's build them. Over to you.

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The Effect of Pre-Service Teacher's Knowledge-Building Activities on Their TPACK Knowledge and Design Belief

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Abstract: This study examines how pre-service teacher's knowledge building activities are related with their technological pedagogical content knowledge (TPACK) and design belief. The data sources included (1) pre-service teachers' online knowledge building activities to discuss and then create a web-based course interface in Knowledge Forum; and (2) the pre- and post-survey using two questionnaires--i.e., TPACK and design belief of teacher (DBT). Using a behavioral sequential analysis, it is found that participants' online knowledge-building activities to create a web-based course interface started from a more divergent process and then moved to a more convergent process. It was also found there was a significant difference in the pre-post change of participants' TPACK ($t=13.692$, $p<.05$) and DBT ($t=9.647$, $p<.05$). Overall, knowledge building activities seem to be conducive to enhancing participants' TPACK knowledge and design beliefs.

Introduction

The rapid technology development in a knowledge society has brought dynamic change in education. Many countries have now attempted to help their students learn with enhanced technologies for developing 21st century skills (e.g., innovative, creative, and design skills). Specifically design capacity to integrate technology-related knowledge for solving real-world problems has become critical for students to success in the future. Accordingly, many inter-disciplinary subjects (e.g., STEM or STEAM) also require student to engage in design and hands-on practices (Mary Dell'Erba, 2019).

In response to this new perspective of student learning, teachers also need to rethink "how to improve their teaching knowledge and accordingly develop proper beliefs, in order to design more effective lessons and activities in various courses to help transform learners into knowledge workers. All of these educational changes in the digital age require teacher to engage in design work and design-oriented thinking (Jim Parsons, Larry Beauchamp, 2012; Sharma Suniti, Lazar Althier M, 2018). Building on the above arguments, it is critical that teachers to develop the necessary design capacity that can help shape the kinds of learning and teaching required in the future knowledge society (Rikke Toft Noergaard, 2017; Mark Burgess, 2018).

Building on the TPACK (technological, pedagogical, and content knowledge) framework, when conceiving and implementing related lesson and activity design works in teachers' daily instruction, they have to exert various types of teaching knowledge to enable good design. And knowledge building (KB), as an innovative pedagogy, may help improve teacher's TPACK knowledge and their design belief (Bereiter & Scardamalia, 2014) as the implementation of knowledge building essentially requires a design-mode of thinking (Bereiter, 2002). Accordingly, the purpose of this study is to investigate whether the participants' (i.e., pre-service teachers) online knowledge building activities (to create a web-based course interface) can help foster these pre-service teachers' TPACK knowledge and design beliefs.

Methods

This study adopted a mixed-method to collect and analyze data. The participating pre-service teachers (N=38) were divided into ten small groups working collaboratively in Knowledge Forum—a knowledge building environment. They followed two iterations of lesson plan to develop and improve their lesson ideas on creating their web-based course interface with a specific, pre-selected topic of their choice/interest. In the process, they tried to capitalize on their TPACK knowledge learned in the teacher education program prior to this course in order to resolve various issues in developing their lesson plan.

In terms of specific knowledge building, students were guided through a process of idea-centered activities to create their web-based course interface as follows: (1) idea/problem germination: participants need to identify the main lesson challenge they want to tackle (e.g., the main challenge identified by group 2 was to teach kids about travel using their geography knowledge by using a website); (2) idea generation: participants started to think about lesson ideas for their web-based course regarding what and how to teach; (3) idea diversification: participants came out with various diverse ideas that might be suitable or not suitable for their web-based course content; (4) idea screening: participants choose the best ideas synthesized from their KF discussion; (5) idea building and testing: all promising ideas were then presented, with other groups help to evaluate the web-based course interface presented, and then give feedback or suggestions for further improvement; (6) idea evaluation and revision: the participants try to revise and improve their lesson plan and web-based course interface design by integrating all suggestions and feedback received.

Before and after the course, two surveys (see Table 1) concerning design knowledge and beliefs (with 7-points Likert scale) was employed and the following analysis was performed using paired-sample t-tests. As for the knowledge building activities/discussion to create the web-based course interface, a lag behavioral sequential analysis (Allison & Liker, 1982) was performed, using a data set of the chronological action automatically recorded in the Knowledge Forum 6 (KF 6) database. Below is the coding scheme of all relevant behaviors identified from open coding (see Table 2).

Table 1 below shows all dimensions of the two surveys.

Dimension	Factors	Reliability
Technological-Integrated Pedagogy and Content Knowledge, TPACK)[1]	Technology Knowledge (TK)	α =0.90
	Technological Pedagogical Knowledge (TPK)	α =0.93
	Technological Content Knowledge (TCK)	α =0.92
	Technological Pedagogical Content Knowledge (TPACK)	α =0.95
Design and Belief of Teacher (DBT)[2]	Lesson Design Practice (LDP)	α =0.94
	Design Disposition (DD)	α = 0.91
	Teacher as Designer (TAD)	α =0.90
	Belief of New Culture Learning (BNCL)	α =0.93

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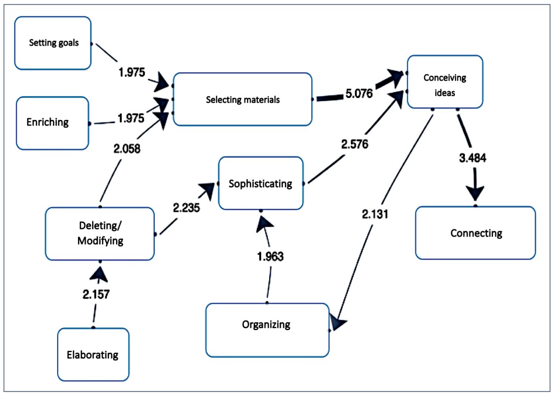
Table 2. Definitions and examples of the coding scheme on knowledge building activities.

Types	Definition
Setting goals	To decide a subject area and a topic to teach and to prepare a draft layout as the initial interface proposal.
Selecting materials	To choose resources or materials that will be shown as web-based course interface components (typically contains teaching videos, graphics or audio materials).
Conceiving ideas	To meaningfully arrange the materials available at hand into a feasible interface, through judgement of one's teacher professional knowledge.
Enriching	To add, supplement, complement, or expand content into the interface.
Sophisticating	To furnish with lots of details or information with sophistication.
Deleting/ Modifying	To refine the design, to revise the original design by deleting or change the existing materials.
Connecting	To establish relationships between isolated or unrelated objects (such as linking picture with a proper title and making them look as a unit).
Organizing	To form small groups using the existing objects or to categorize them into a genre .
Elaborating	To give meaning via providing such as heading or title to specific picture/notes post, so as to enable viewers to understand better what each object means in the web-based course page.
Beautifying	Adding some decorations and convert the all words/files/documents into an illustrating chart.
Simplifying	To reduce redundant or lengthy words or structures, and to clean messy webpage, making it simpler for viewing.
Integrating/ Consolidating	To combine each independent section into a whole by integrating chapters, units, sections etc.
Presenting	To present their finished project to others or to re-present after improvement from the collected feedback or suggestions.

Result

The pre-service teachers developed and discussed their final project (i.e., online web-based course interface) in the knowledge building environment. Firstly, regarding knowledge building process, the findings from the behavioral sequential analysis showed that in the earlier KB stage (using midterm as a separation point) (see Figure 1, left) there were more divergent activities of choosing learning material for students, conceiving ideas, reorganizing ideas, and combining information, selecting, deleting, or modifying what has been discussed as learning contents, etc., in order to include as much ideas and information as possible. The KB process showed an overall idea diversification pattern for the participants' work for their web-based course interface. In contrast, in the later KB stage, the findings showed a more convergence pattern (see Figure 2, right) in that KB activities tended to focus on simplification and beautification of the interface, supplement and integration of all previously gathered information for the participants' work for their web-based course interface.



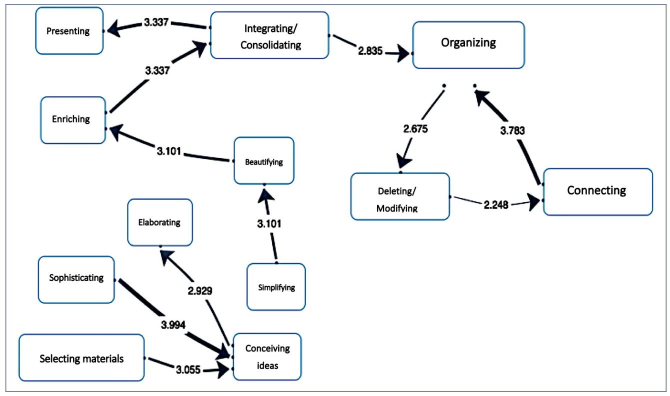


Figure 1. Behavioral differences in terms of the web-based course interface design between the two KB stages

**Note: (1) The adjusted residual is calculated by the z score of Allison & Liker (1982). If it exceeds 1.96, it will reach 0.05 significant level, indicating that the number of sequences is significantly higher. (2) The correlation coefficient is calculated using Yule'Q, between -1 and 1. Greater than 0 is a positive correlation and less than 0 is a complex correlation. Absolute value 1 is completely correlated, 0.7 to 0.9 is highly correlated, 0.4 to 0.6 is moderately correlated, 0.1 to 0.3 is low correlation, and 0.1 or less is uncorrelated.*

Below we briefly elaborate the behavioral transition from one to another as showed in Figure 1. At the beginning of the semester, for example, some pre-service teachers are interested in teaching kindergarten children about traffic laws, so they set this up as a teaching goal for creating their web-based course interface **(Setting goals)**. Next, some traffic signs were searched online, selected, and provided, such as pictures about traffic cone signs **(Selecting materials).** Immediately following this behavior, a name was given under the cone picture as "Activity 1" **(Elaborating)**. Sometimes after discussion, the group may decide that the designed or chosen material was not attractive, so they deleted this picture and change it with another more colorful and freshness images. For instance, one group's goal was to each cooking, and because the previously chosen teaching materials (which is a picture of vegetable) looks not so fresh, so they deleted and replaced it with a new one **(Deleting/ Modifying).** On the contrary, sometimes a group might also add some other more content to enhance the original arrangement, such that this same group added some safety information they thought that learner should acquire before they start their cooking course **(Enriching).**

Without a goal in mind, ideation follows to help create the web-based course interface with moving the selected materials around here and there **(Conceiving ideas)**. After that, the group members tried to make connections between the objects/figures/materials they chose to form a story or a paragraph of description required in a cover story **(Connecting)**. As conceiving ideas, groups often start to organize and re-organize ideas and materials. For instance, the group that intends to teach cooking tried to merge three seemingly separated cooking units together into one chapter **(Organizing)**. Oftentimes, a group failed to form a meaningful organization, so they keep adding things into the entire page with details, thus making the page become complicated but messy and with no focus **(Sophisticating)**.

At a later stage, some behaviors were repeated to minimalize the components in the page **(Simplifying).** For example: One group wanted to teach using Google Map, but there are too many details of processing the application Google Map in one page, so these details were being merge into a package of file instead. Some groups also tried to turn their learning materials using a series of words into a chart that is taken from some computer games to make the interface looked nicer **(Beautifying)**. Lastly, as can be seen the design of a web-based course contains activities, with each being integrated from different units from various sections **(Integrating/Consolidating)** in order for them to present their project more effectively as the final behavior in the course **(Presenting)**.

Secondly in terms of KB outcomes, the results from quantitative questionnaires showed that pre-service teachers have significantly changed their TPACK knowledge and design beliefs through online KB activities (TPACK, $t=13.629$, $p< .05$; DBT, $t=9.647$, $p<.05$) (see Table 3 and Table 4 below). Figure 3 further show an example of the web-based course interface created by a group of students.

Table 3 Technology-related TPACK using Paired Sample t-Test

	Pre-Survey		Post-Survey		t
	M	**SD**	**M**	**SD**	
Technology Knowledge	5.789	0.899	6.184	0.793	5.478*
Technological Pedagogical Knowledge	4.174	0.930	5.458	0.813	11.931**
Technological Content Knowledge	4.421	0.976	5.560	0.892	11.525**
Technological Pedagogical Content Knowledge	4.342	0.908	5.572	0.824	9.923**
Technology-Integrated Pedagogy and Content Knowledge (TPACK)	**4.682**	**0.123**	**5.085**	**0.115**	**13.629****

*p<.05 **p<.001

Table 4 Design Belief of Teacher using Paired Sample t-Test.

	Pre-Survey		Post-Survey		t
	M	**SD**	**M**	**SD**	
Design Disposition	4.849	0.143	5.668	0.130	7.999*
Lesson Design Practice	4.711	0.121	5.588	0.136	10.213**
Belief of New Culture Learning	5.300	0.133	6.063	0.126	9.165**
Teacher as Designer	5.480	0.162	6.131	0.130	5.786**
Design Belief of Teacher	**5.085**	**0.115**	**5.863**	**0.112**	**9.647**

*p<.05 **p<.001

Figure 3. On the left side of the figure, it shows one group's web-based course interface focusing on the topic of travel and geography in the earlier KB stage. The first stage showed a complex but detailed content of interface, indicating that these pre-service teachers' intention to teach a lot of separate units using a very linear teaching approach. On the right side, the figure showed the same group's improvement in later KB stage for the web-based course interface. It became a clearer and more structured interface which has been simplified by using a metric array to present the learning units.

Conclusion

In the present study, knowledge building activities which require the participating pre-service teachers to integrate technology into their lesson plan while creating a web-based course interface, is found to improve teacher's TPACK knowledge and design beliefs. The behaviors sequential analysis of the participants' KB activities showed that they progressively demonstrated some higher-level knowledge or skills, such as: conceptual placement, integration, organization, etc., which are more complicated and advancement (upward) integration, this is crucial important on developing novice teacher's lesson design practice.

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Dynamic Knowledge Graph: A Tool for Fostering Conceptual Change in Knowledge Building Community

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Abstract: In this short paper, we introduce a work-in-process tool called Dynamic Knowledge Graph (DKG), which is designed to facilitate conceptual change in knowledge building environments. The main function of DKG is to support higher conceptual change by turning current artifacts in the form of Knowledge Forum notes into instructional resources. DKG can provide relevant dynamic knowledge graphs that reflect core concepts and its relationships that are mined from current artifacts for learners. Preliminary study suggested that the DKG could be further improved and we conclude this paper by discussing its current limitations and future directions.

Introduction

Knowledge building (KB) is defined as the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2014). It attaches importance to conceptual engagement and contribution, which can help students to obtain the essence of scientific concept and develop new knowledge. Efforts are made in the KB community to advance conceptual change. Burtis, Chan, Hewitt, Scardamalia and Bereiter (1993) investigated this possibility that KB fosters conceptual change of students using CSILE, a predecessor to Knowledge Forum (KF). Furthermore, students who maintained knowledge-building goals and evaluated their ideas in the context of the writings of the scientific community beyond their classroom succeeded in attaining critical conceptual change (Oshima & Scardamalia, 1996). Especially, high-conceptual-progress students in KB were more concerned with constructing their knowledge centered around problems, whereas low-conceptual-progress students were more involved in accumulating referent-based knowledge (Oshima, Scardamalia & Bereiter, 1996).

On the other hand, KB as a mediator of conflict in conceptual change helps to highlights the importance of students' constructive activity in learning (Chan, Burtis & Bereiter, 1997). In one study, when students inquire and reflect on their understanding in the context of KB community knowledge, they may advance in their individual and group learning that predicted subsequent conceptual change (Lam & Chan, 2008). Likewise, students in KB were able to recognize a gap or conflict in their knowledge and willingly sought information to improve their naive conceptions (Khanlari, Bereiter & Scardamalia, 2016). A further educationally significant finding is the willingness of students to take collective cognitive responsibility to improve the knowledge of the community and solve their peers' misconceptions. If KB technology is indeed becoming smarter, supports for self-organization around conceptual contributions to encourage emergent conceptual change are needed. What is missing in current knowledge-building environments is a mechanism to explicitly support such collaborate conceptual change using data-intensive analytics (Chen & Liu, 2016). To this end, we developed DKG in knowledge building community to explore this possibility.

Knowledge Graph in Conceptual Change

As an integrated information repository, knowledge graph interconnect heterogeneous data from different domains. A prominent example is Google's knowledge graph, which represents real-world entities and relationships through multiple relational graphs (Chen et al., 2018; Rizun, 2019). In education domain, knowledge graphs are often used in school subject teaching, also known as concept maps. For students, understanding and applying the logical relationships between entities or concepts requires more cognitive engagements. Because the nodes of the knowledge graph link entity information, it can promote deeper learning within a certain domain. Moreover, due to the concealment of group information and learning processes, it is necessary to visualize the consensus content through group awareness, so as to promote active learning (Bodemer & Dehler, 2011). Using the knowledge graph, teachers and students can interact with others through knowledge nodes and relations, explore collaborations and track rea-time changes (Rafols, Porter, & Leydesdorff, 2010).

Several studies have clearly demonstrated the effectiveness of knowledge graphs in supporting the conceptual change. Knowledge graphs can reveal interesting information about the process of knowledge restructuring that is assumed to happen in conceptual change, which have been used in science education as tools for supporting students' learning of the structural nature of physics knowledge but also as tools for assessment and evaluation of learning (Goldwater & Schalk, 2016). The method of knowledge graphs emerged to leverage the understanding of the process of conceptual change in science (Novak & Musonda, 1991), growing out of theories describing cognitive structures recognizing the interrelatedness of concepts as an essential property of knowledge (Ruiz-Primo & Shavelson, 1996). When knowledge graphs are used repeatedly over time, conclusions concerning the development of knowledge can be drawn. How knowledge develops for a group of learners can reveal information about core concepts and misconceptions that may hinder the learning progress at a certain stage and which teachers can then approach in the classroom. Moreover, knowledge graphs can yield valuable information for teachers by allowing them to see common elements that their students did not yet fully understand or that are prone to misconceptions (Duit & Treagust, 2003). In a longitudinal study, the changes in students' knowledge structures were examined through knowledge graphs. Besides a growth of the knowledge network, the results indicated a reorganization, with first a fragmentation during the unit, followed by an integration of knowledge at the end of the unit. Moreover, the terms used in the knowledge graphs varied in their centrality, with more abstract terms being more central and thus more important for the structure of the graph (Thurn, Hänger & Kokkonen, 2020).

Such knowledge graphs are usually constructed by experienced teachers or domain experts in manual way. However, such a manual construction process is actually time-consuming and not scalable to large number of concepts and relations. On the other hand, the manual construction approach is error-prone: according to the pedagogical research, there often exists expert blind spot (Nathan & Petrosino, 2003), which means expert's cognition and learner's cognition on the same concept often do not well align. As a result, those manually created knowledge graphs can be suboptimal or misleading for learners.

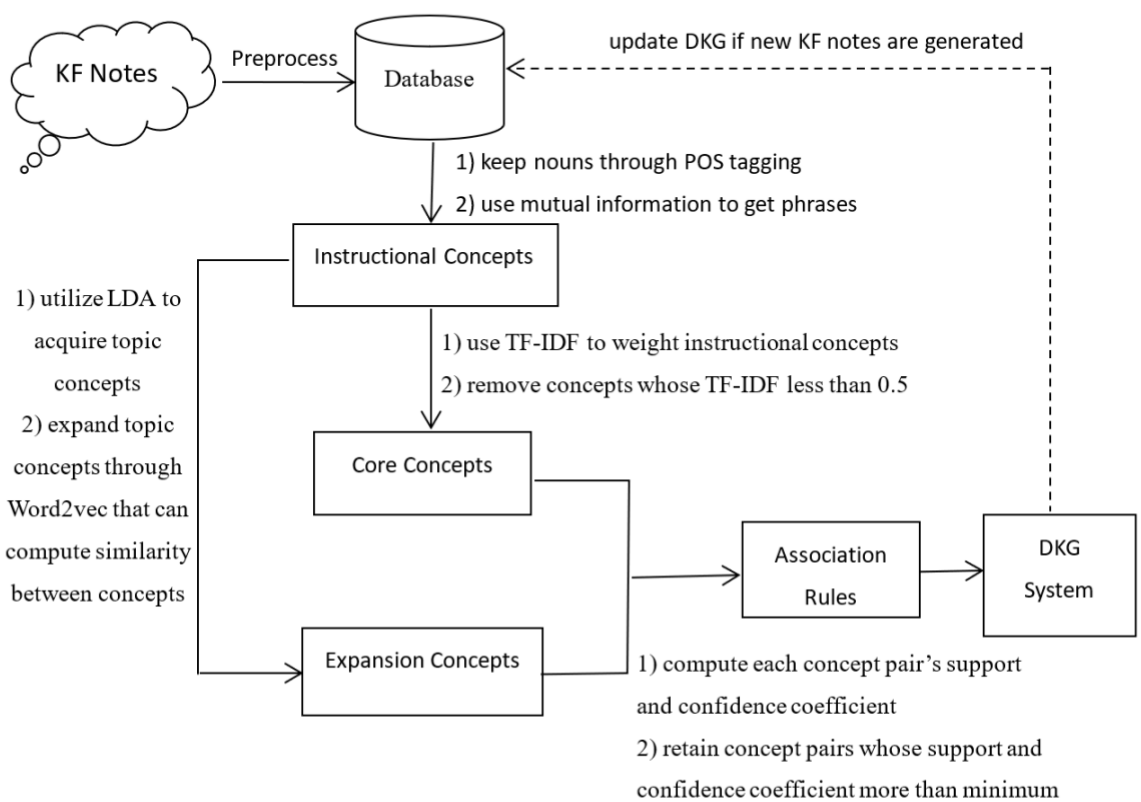

Figure 1. A flow chart of the DKG.

Dynamic Knowledge Graphs

Motivated by the increasing demands for knowledge graph in KF and the limitations of manual construction approach, we propose DKG to automatically construct educational dynamic knowledge graphs that can be used for teaching and learning in knowledge building community. To begin with, the desired nodes in knowledge graphs of KF represent instructional concepts in subjects or courses, so the extraction requires KF data from students' notes. In addition, the relations between instructional concepts reflect learner's cognitive and educational process. Such relations are relatively difficult to identify without proper analysis and modeling on the specific KF data. Below, we briefly explain the current technical implementation of DKG.

The algorithmic computation that powers DKG is illustrated in Figure 1. The computation includes three phases. First, the main function of primary stage is to extract instructional concepts from KF notes, which need to be firstly converted from KF notes into machine-readable text format. A part-of-speech (POS) tagging algorithm can be employed to extract particular concepts. And then TF-IDF (Salton & Buckley,1988), LDA (Blei, Ng & Jordan, 2003) and Word2vec (Li et al., 2019) are used to select core concepts and expand the size of concepts corpus. To be specific, TF-IDF algorithm can sort high-frequency core concepts, afterwards we retain the concepts whose TF-IDF value is higher than 0.5. In addition, LDA can find the subject terms from the semantic perspective, which can be expanded through Word2vec deep learning package.

The second phase is to identify the educational relations that interlink instructional concepts to help the knowledge building process directly. Since educational relations are abstract, this module utilizes data mining technique, such as the association rule mining (Agrawal & Srikant, 1994). The number of texts appearing in A word and B word is C_A and C_B respectively, the total number of texts is C_T. Then, according to the co-occurrence matrix, the total number of $C_{A\cap B}$ occurring in all texts for each word pair {A and B} is obtained. The support coefficient describes the words A and B appear simultaneously in all texts is calculated as follows: Support $(A \rightarrow B) = P(A \cap B) = C_{A\cap B}/C_T$. The confidence coefficient describes the probability of the occurrence of the text of word A and word B. The calculation formula is as follows: Confidence $(A \rightarrow B) = P(B|A) = C_{A\cap B}/C_A$. For each word pair {A→B} in this study, the support is greater than or equal to the minimum support, and the confidence is greater than or equal to the minimum confidence.

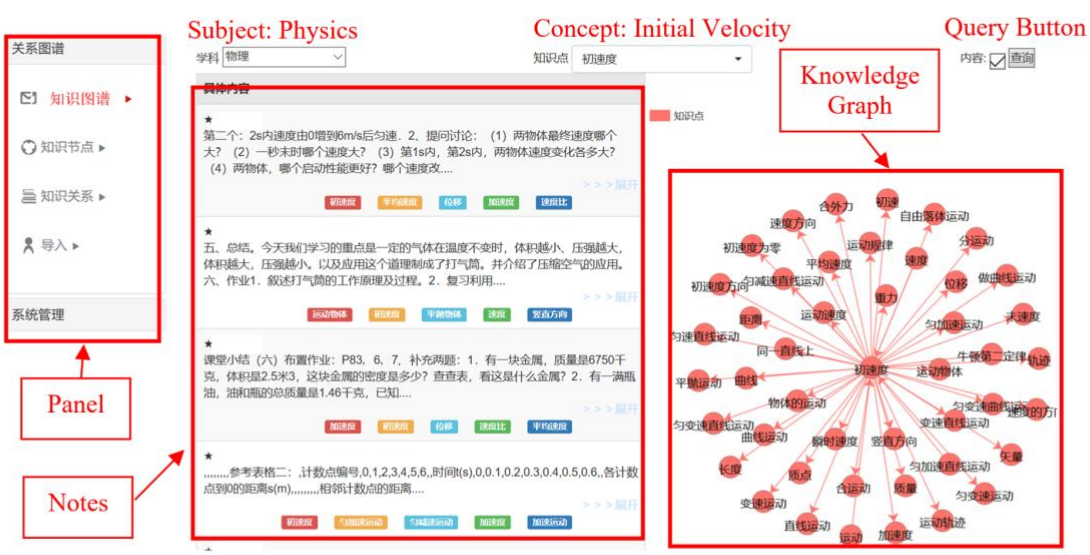

Figure 2. A snapshot of the DKG system. The panel includes four functions: knowledge graphs, knowledge nodes, knowledge relationships and import function. In the knowledge graph page, the user can select the specific instructional concept (e.g., initial velocity), and then click the query button to view the relevant knowledge graph and notes, which can help users track changes in the structure of core concepts.

Finally, dynamic knowledge graphs are displayed in the knowledge graph management system (see Figure 2 and Figure 3). In Figure 2, the core concepts and its relations returned by the computation. In this display, the users can simply select a concept to query related knowledge graphs and corresponding note contents, meanwhile, the users can manually add knowledge nodes and establish knowledge relationship, which is a thoughtful design. In Figure 3, the users have access to the whole knowledge graph of one certain subject in KF, who will have a clear idea of the position and importance of a particular concept in the overall knowledge graph, as well as its relations with other concepts.

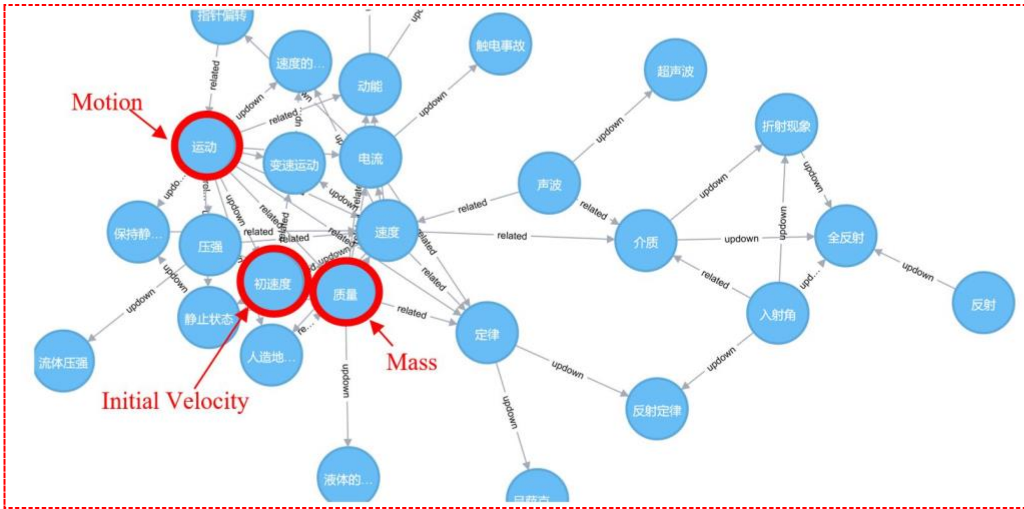

Figure 3. Exemplary Knowledge Graph of Physics in DKG. This knowledge graph is constructed from the KF notes of the movement chapter in junior middle school physics. We can find that the instructional concepts of motion, mass and initial velocity are all at the core of the knowledge graph, which are of great significance for fostering conceptual change in knowledge building.

Preliminary Studies

A knowledge graph can be regarded as a network consisting of nodes (also called vertices) and links (also called edges) between them, which enables the application of graph theory on knowledge graphs (Chen, Chang, Ouyang & Zhou, 2018). Regarding the centrality of certain nodes, several measures exist, from counting the number of edges per node (degree centrality), over the average shortest path length to all other nodes (closeness centrality) to the number of paths that cross through a certain node (betweenness centrality). Each centrality measure answers a slightly different question. Moreover, as a comparison measure, we applied PageRank centrality that takes the number of (incoming) edges but also the importance of adjacent nodes sending these edges into account. In contrast to the aforementioned centrality indices, PageRank centrality weights each edge differently according to the importance the node it emerges from.

We used Python for all analyses, with the following packages in alphabetical order: igraph, json, lxml, matplotlib, numpy, pylab, re, scipy, scrapy, xlwt. As centrality indices strive to identify the most influential nodes, they are less suited for the nodes with low centrality and do not necessarily express a meaningful order of such nodes with lower centrality because of a lack of sensitivity. Thus, we focus on the centrality statistics for the representative nodes, such as motion, mass and initial velocity (See Figure 3). The result of graph analysis is reflected in Table 1.

Table 1: Graph analysis: Most central nodes indicated by degree, closeness, betweenness and PageRank given for comparison.

Central Nodes	Degree	Closeness	Betweenness	PageRank
Motion	21	0.0124	1028	0.049
Mass	8	0.0123	959	0.022
Initial Velocity	2	0.0123	1.537	0.004

The term conceptual change is often associated with changes in the deeper, underlying knowledge. The process of conceptual change, however, comes in degrees. At the most basic level, conceptual change is associated with assimilation of new knowledge and facts into the existing knowledge structure, enriching it (Vosniadou, 1994). In terms of Table 1, the concept of motion has the largest degree, indicating that it occupies an important position in the network. By contrast, the degree of mass ranks second, and the degree of initial velocity is the smallest, indicating that initial velocity is less important than motion and mass, which is also consistent with the topic of "movement in physics". Furthermore, the closeness of the three concepts imply that they are all relatively close to the other nodes. As for betweenness and PageRank, motion and mass are similar, but the value of initial velocity is smaller. There is a proof that explains strong connections between motion or mass and other instructional concepts. However, initial velocity shows less potential to link other important concepts. According to Newton's first law (the law of inertia), the relationship between motion and mass is very tight, which are also crucial nodes in the movement chapter in junior middle school physics. It is natural to conclude that the graph analysis results conform to the corresponding instructional content and can reveal the core concepts structure and its relations, which input impetus to help KB teachers track and compare the changes of students' conceptual networks over time. In other words, the dynamic knowledge graph shows great prospect for promoting and evaluating students' conceptual change in the knowledge-building classrooms.

Discussion and Conclusions

In this short paper, we introduce DKG, an ongoing feature, developed to generate knowledge graphs in a knowledge-building community. The central affordance of DKG is to turn KF notes in a community into resources for continuous knowledge building, by feeding pertinent knowledge graphs to learners. The algorithm that powers DKG is not complex and open to further refinement. But the tool itself is of significance in facilitating conceptual change with dynamic knowledge graphs in knowledge building. Benefits of such scaffolding mechanisms are demonstrated in earlier design research using networks (Oshima J, Oshima R, & Matsuzawa, 2012). With DKG, we attempt to make such scaffolding efforts even more dynamic, concurrent and automatic. Planning of new design research initiatives is underway to develop pedagogical principles for incorporating DKG in knowledge-building classrooms.

In the first step, teachers can examine what concepts are unknown before teaching. To survey to what extent new concepts are understood, teachers could examine whether new concepts are meaningfully incorporated into the knowledge graph and check on possible misconceptions. Similarly, if the centrality analysis is adopted, the important concepts of high centrality can also be considered to diagnose the change of students' knowledge structure. Teachers can also ask students to compare the final knowledge graph with the expert knowledge graph. Students can be prompted to identify important differences between the two graphs and to reflect on what they can improve. Such comparison can enable students to deeply analyze their own ideas from the perspective of experts, thus helping them to better integrate new knowledge.

In addition to graph analysis reported earlier, there are several challenges we need to figure out. First, the integration and real-time performance of DKG need to be further improved. Currently, DKG relies on manual import of KF notes, so there is no way to seamlessly carry out the whole process of data collection, graph construction, graph analysis and graph update. Second, association rules algorithm should be further subdivided. According to the degree of support and confidence coefficient, association rules can identify three types of relationships: basic relationship, advanced relationship and peer relationship. Finally, we want to give users, including teachers and students, a chance to bring an impact on DKG. By doing so, future versions of DKG will solicit input from users, thus "collaborating" with them rather than forcing advice on them. Besides, students' construction of dynamic knowledge graphs through DKG can potentially provide important motivation for long-term knowledge building and higher level of conceptual change.

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Extending Co-Created Cross Community Knowledge Building Discourses

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Abstract: Connecting knowledge communities and databases at a higher social level have been suggested as one of the main focuses for the future knowledge building community and the field of learning sciences (Scardamalia, et al 2017; Stahl, 2013). Bringing Knowledge Building classrooms together and sustaining inquiry-based learning needs new technology and creative designs to facilitate the process over time and across spaces. Innovative research is needed to bridge discourses and practices across Knowledge Building communities over time more smoothly and productively. This study attempts to address this challenge by using a multi-level interaction framework in grade 5 science communities.

Conceptual Framework

Studies have shown that students interacting with multiple communities may have access to new information, gain more learning opportunities, and have a higher motivation (Brown, 1992. Decuyper, Dochy, & Van Den Bossche, 2010). Some studies reveal that community learning may face challenges like ineffective learning outcomes due to poor task design or complicated interaction processes (Mittelmeier et al., 2018). Few studies explicitly addressed the benefits of learning across communities (Rienties and Tempelaar, 2017). Boundaries exist between communities, ideas, identities, structures, institutions, and other entities. Star and Griesemer (1989) assert that boundaries' complexity and ambiguity make them full of potential new possibilities. Existing studies have mainly focused on the inquiry discourse for individual classrooms, and the discourse mainly focuses on the single community level. However, research gaps persist in how students extend their interaction with other communities to sustain and build-on their authentic inquiries over a long time; more studies are required to understand the nature of boundary objects and boundary-crossing learning processes for knowledge creation over time.

Cross-community interactions using boundary objects

The boundary object with the same structure can facilitate the information transition between different communities, which can also be interpreted differently depending on the community's needs (Star and Griesemer,1989). In this study, the boundary objects take the form of Journey of Thinking: a reflection summary with the same structure created by students and their learning processes. After the Journey of Thinking is generated, it is further shared and reviewed with other communities in a shared online space. This synthetic boundary object-Journey of Thinking enables individuals to understand the discussion and extend inquiry progress in other communities. With careful sharing, reading, and building-on, these Knowledge Building behaviors further sustain the cross-community interactions. The newcomers can access the existing knowledge with a clear purpose facilitated by Journey of Thinking. As members access diverse ideas and in-depth thinking beyond their current community, extended connections and insights from the broader scale expand the inquiry process and enrich the research contexts (Zhang, Tao, Chen, Sun, Judson & Naqvi, 2018). Students can conduct advanced research according to the emergence of new challenges or new research inquiries along with Journey of Thinking readings and writings.

The downward impact of cross-community dynamics on within-community inquiry and discourse

The Downward causal effect refers to the impact of the emergent macro-level interactions on micro-level KB activities. It is reflected in two aspects, as elaborated below. On the one hand, students co-generate the interactional frame of Knowledge Building norms, metacognitive meeting rules, distribute workloads and collective responsibilities in each group, and co-generate the online discussion norms. These emergent collective actions then regulate and promote their collective actions. These two processes are inseparable and happen simultaneously, which means that the emergence of students' KB discourse, behavior patterns, and KB norms contributes to the continuing process of collaborative inquiry. However, at the same time, it regulates and accelerates students' behaviors in shared KB environment culture by the mutually agreed norms that are created at that moment. The stable material content structures and discursive patterns guide, direct, and constrain individuals. However, this guidance and constraint often contain a contingency that is never fully constrained, as the emergence frame is continually evolving. On the other hand, the collective knowledge of the classrooms has to tap into the knowledge accumulated at the individual class level because the individual class is the basis of organizational knowledge creation. "Super Talk" is the collaborative online space where students from the four classes work together to address the same challenging problem. The learning results also impact and transform the dynamic learning back to each class and the individual student. The accumulation of knowledge created in the online space will leverage each classroom's understanding when a student acts as a boundary broker, bringing these new insights back to their home classes. It leverages the home class's understanding and creates new opportunities to reorganize the current classroom's accumulation of knowledge. The collaborative space and boundary objects not only provide students with an infrastructure that enables knowledge creation across communities but also the knowledge infrastructure provides inquiry and learning with a trustworthy, vetted background database created by students.

Methods

Technology and classroom contexts

Drawing upon the results of the previous two years' research (Zhang, Bogouslavsky & Yuan, 2017, Yuan & Zhang, 2019), the research team has been continuously developing and revising features of a new technology tool called Idea Thread Mapper (ITM), an innovative tool embedded in Knowledge Forum to further support students' collaboration both within and across communities (Chen & Zhang, 2016).

This study was conducted in four grade 5 classrooms (with a total of 89 students who were 10-to-11 years old) that studied human body systems over six months using ITM. The four classrooms, labeled as Class 1-4, were taught by two teachers, each teaching two classes. Students in each classroom generated interest-driven questions, co-created wondering areas focusing on various human body systems, and conducted research using various resources. They conducted reflective knowledge-building conversation (called "metacognitive meetings") in their classroom to build on one another's questions and ideas while reviewing their progress. The conversation continued on ITM in their online discourse space organized as various idea threads, each addressing an overarching problem/theme. As progress is made in each idea thread, students co-created and edited *Journey of Thinking* to reflect on their knowledge (Figure 1). The Journey of Thinking was then shared with all the other classrooms. Drawing upon their knowledge built about the various body systems, students in Class 3 proposed a challenging problem for "Super Talk" across the classrooms at the beginning of the 6th month. The other classrooms supported this proposal. Students from the four classrooms worked together to discuss this overarching question. Near the end of the unit, each class had a metacognitive meeting to review knowledge gained from the "Super Talk" and build connections with the different human body systems. To understand how students interact across classrooms, this study attempts to address this challenge by asking three major questions :1) How did students co-create knowledge-building discourses to address challenging research at a higher social level? 2) How did students' within-classroom and between-classroom knowledge building discourses change before and after the cross-classroom interaction? 3) How did the teachers facilitate cross-classroom interactions?

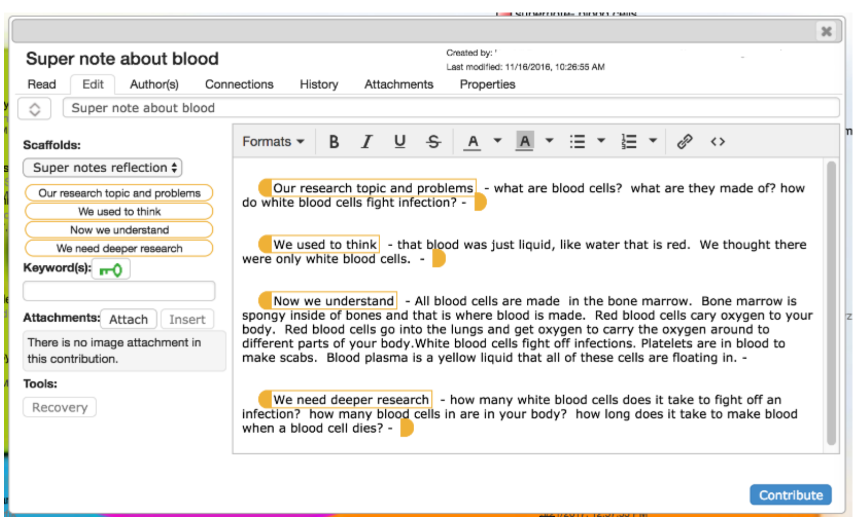


Figure 1. The Journey of Thinking Created by Blood and Cells Group in study-1 using the Journey of Thinking scaffolds: Our research topic and problems, we used to think, now we understand, we need deeper research.

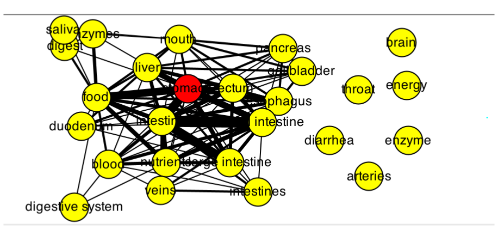
Results

How did students co-create knowledge-building discourses to address a challenging research at the higher social level?

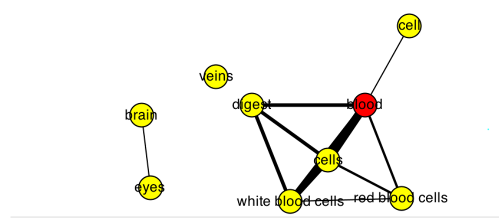
To understand how students collaborate with peers from other communities via "Super Talk," researchers examined the "Super Talk" discourse with 22 students participating in the discussion from four classrooms. Students collaboratively answered the research question from Bone and Muscles, Brain and Nervous systems, Cells and Genetics, and Digestive systems. Approximately 50% of the notes are built-on, reflecting a higher level of student collaboration and knowledge build-on. 86% of the notes show a higher level of elaborated explanations (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007), which shows students' efforts to produce high-quality notes in the "Super Talk."

How did students' within and between-classroom knowledge building discourses change before and after the cross-classroom interaction?

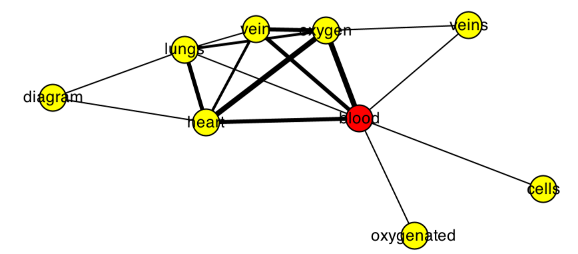
To understand how the within-classroom discourses changed over the six months. A discourse analysis software KBDex (Oshima, 2012) was used to examine how the key concepts co-created from students' face-to-face metacognitive meetings changed over time. The researchers selected one metacognitive meeting from each month to trace the changes of the key concepts from Class 3 (labeled as metacognitive meeting 1-6). The results show several patterns: at the beginning of the semester, students' main focus was on individual organs, for instance, muscles, blood, and brain, respectively. However, in the middle, students started to learn inter-connected concepts between two or more systems. In the last month, the central concept was the cell, representing the main cutting-edge concept that connects every other human body organ (Figure 2).



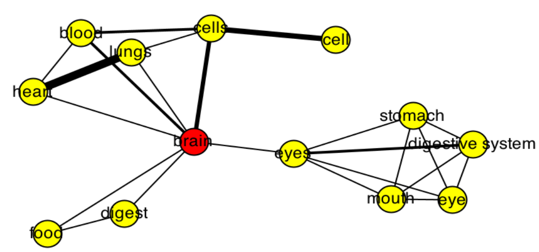
Class 3's Metacognitive Meeting-1



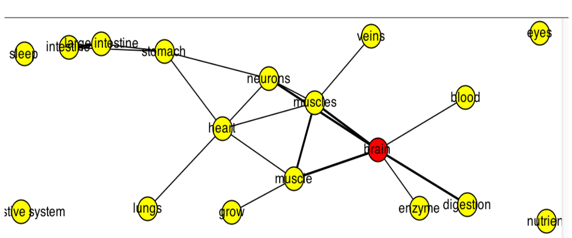
Class 3's Metacognitive Meeting-2



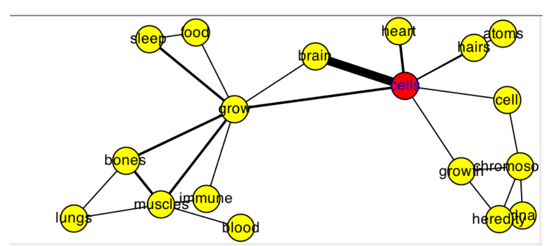
Class 3's Metacognitive Meeting-3



Class 3's Metacognitive Meeting-4



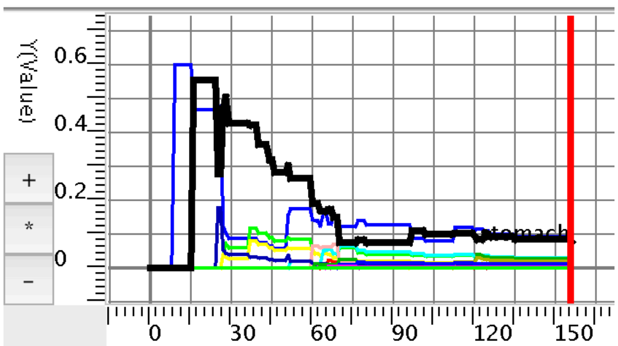
Class 3's Metacognitive Meeting-5



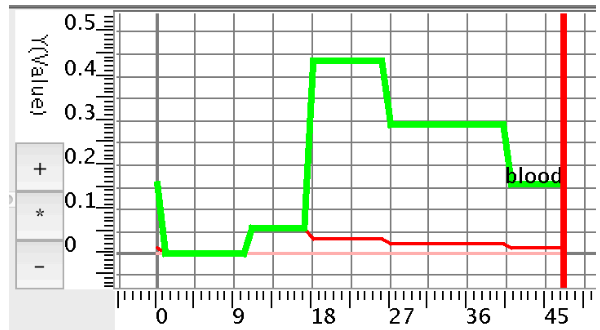
Class 3's Metacognitive Meeting-6

Figure 2: The changes of the main concepts of the metacognitive meetings from the 1st month to the 6th month. (red represents the main systems students mentioned)

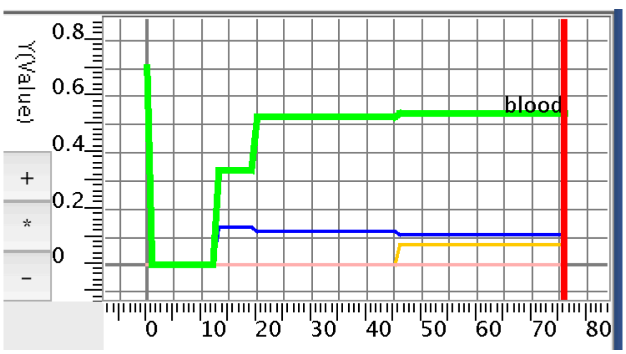
Furthermore, the researchers analyzed each main concept's betweenness centrality (Figure 3). The results support the changes mentioned above. Before the cross-classroom interaction, students gradually built up their knowledge blocks from each concept. As time goes by, they understood the overarching relationships. For instance, in the fourth and fifth months, the concept "Brain" stood out as having the highest betweenness centrality among the discussed concepts, suggesting that students' discourse positioned the brain as the central topic connected with other systems. They consider the brain was the main concept that bridges other separate concepts. However, after the cross-classroom interaction, due to the broker who brought back the fundamental concept, cell, to the local community's discussion, students made extensive connections and considered cells as the fundamental concept that bridges other human organ concepts (Figure 4). As the results show, the concept of "Cell" had the highest gain in betweenness centrality. Student K12, who acted as broker, brought back the concept of cell mitosis from the Super Talk and triggered extended discussion related to cells in the home class. According to the science standards, the concept of cell and mitosis is required by Grade 8 and Grade 9-12, respectively.



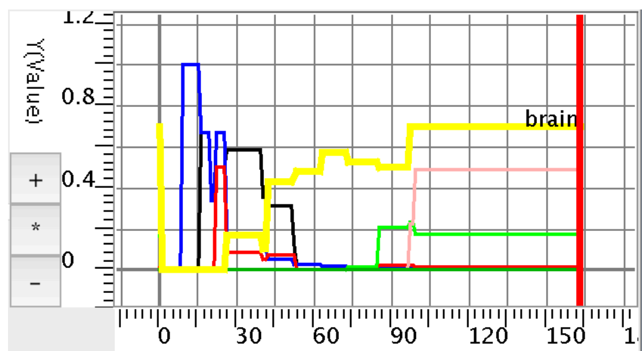
Class 3's Metacognitive Meeting-1-Stomach



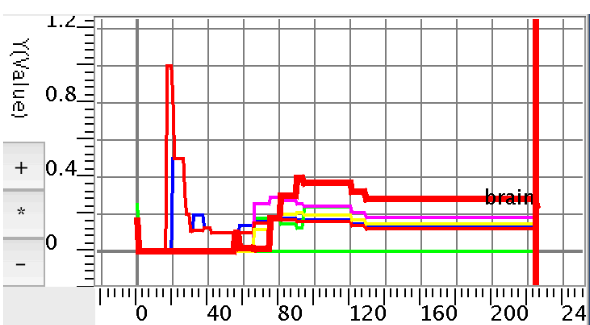
Class 3's Metacognitive Meeting-2-Blood



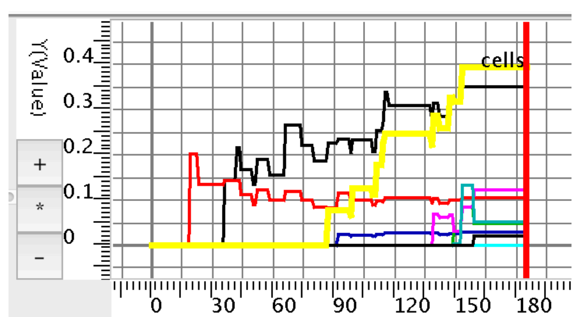
Class 3's Metacognitive Meeting-3-Blood



Class 3's Metacognitive Meeting-4-Brain



Class 3's Metacognitive Meeting-5-Brain



Class 3's Metacognitive Meeting-6-Cells

Figure 3. Betweenness centrality of the key concepts discussed in the metacognitive meeting before and after the "Super Talk" meeting over the six months.

How did the teachers facilitate the cross-classroom interactions?

To understand how the teacher facilitates the cross-classroom interaction, the researcher applied a new set of metacognitive meeting coding schemes (Yuan & Zhang, 2019). The metacognitive meeting has many formats and has been held to address different questions under different circumstances; for instance, the metacognitive meetings were held with specific themes at the beginning of the semester. Towards the end of the semester, the metacognitive meetings focused on connections between various expert areas. Through the qualitative analysis of the metacognitive meetings' video recordings, the researcher found several main patterns of how the teachers facilitate the metacognitive meetings to deepen students' conversation in idea advancement. For instance, at the beginning of the metacognitive meeting, the teacher first directed the discussion by highlighting the main concepts and then opening up the conversation by giving students a chance to share. Instead of directly offering the knowledge in the middle of the conversation, the teacher deepened the conversation by continually asking updated questions for clarification and explanation. The teacher invited other students to join the conversation to contribute their knowledge to the focal research question and give positive feedback and confirmation. Finally, the teachers ended up the conversation by summarizing the information that students mentioned and encouraged them to reflect on their learning experiences.

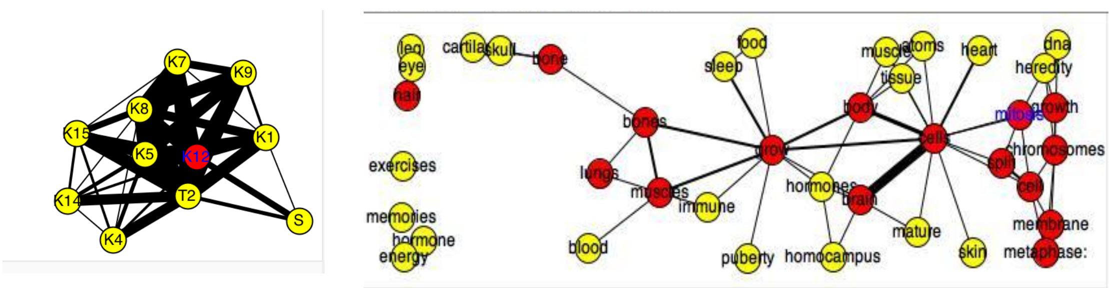


Figure 4. Student K12 from Class A brought in a major concept from "Super Talk" back to the home class and triggered extended connections in MM

Scholarly significance of the study or work

Based on the results mentioned above, this study sheds light on the possible designs and processes to enable collaborative knowledge building across a network of classrooms in a broader learning environment and ongoing learning process. The findings elaborated on a multi-level, emergent interaction approach to supporting student knowledge building in their local and cross-community spaces over an extended period. It is crucial to approach collaborative knowledge space as an essential component of learning space design for learning communities. This study also further demonstrates the possibility to extend the design of collaborative knowledge space to include a cross-community layer.

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The Development of Students' Knowledge Building Competence: A Longitudinal Study

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Abstract:
Students may develop their Knowledge Building understanding and competence as they engage in Knowledge Building practice. However, few studies have examined the development of students' Knowledge Building competence from a longitudinal perspective. This study defines students' Knowledge Building competence as their ability to engage in and contribute to Knowledge Building discourse. This exploratory research tracks a group of 20 students from grade 1 to grade 3 and studies how their Knowledge Building competence develops. The preliminary results indicate that the students' Knowledge Building competence tends to increase, suggested by the increasing percentage of contributions such as elaborated integration and student proposals. The results also suggest that all the participants have greater contributions over the years. Qualitative analysis of representative students' Knowledge Building trajectories is in progress.

Introduction
Knowledge Building is a socio-constructivist approach with theory, pedagogy, and technology aligned (Scardamalia & Bereiter, 2006, 2014). It advocates students taking responsibility to deal with the emergent and unpredictable needs of knowledge work and continuously advance community knowledge. Taking collective responsibility requires students to know "what needs to be known" and ensure others "know what needs to be known" (Scardamalia, 2002, p.2). Therefore, students need to engage in high-level cognitive work such as deciding what to explore, planning how to achieve shared goals, evaluating community knowledge status, identifying knowledge gaps, and adjusting community goals, which are usually assumed by teachers (Scardamalia, 2002). Although previous studies suggest the effectiveness of this high-level cognitive work on helping students advance community knowledge (e.g., Resendes, Scardamalia, Bereiter, Chen, & Halewood 2015; Yang, van Aalst, Chan, & Tian, 2016), it should not be taken for granted that students could deal with the high-level epistemic agency and engage in Knowledge Building (authors).

Students improve ideas by engaging in progressive Knowledge Building discourse (Scardamalia & Bereiter, 2006). Progressive discourse is about identifying weaknesses and achieving greater explanatory coherence of ideas (Thagard, 2007). Explanatory coherence can be judged from two perspectives: explaining more phenomena and facts and deepening the explanation of why the theory works (Thagard, 2007). Knowledge Building discourse includes face-to-face Knowledge Building Circle discourse and online Knowledge Forum discourse. In a Knowledge Building Circle, a teacher and students sit in a circle that everyone is equal to participate in peer-to-peer discourse to collectively develop norms and build ideas (Reeve, Messina, & Scardamalia, 2008). Knowledge Forum is a software environment developed to support Knowledge Building practice (Scardamalia, 2004). Knowledge Forum enables students to contribute to a shared space, to read and build on ideas, to introduce authoritative sources, and to rise-above diverse ideas.

Researchers have developed different approaches or instruments to analyze students' Knowledge Building discourse concerning various types and depth, which indicate students' Knowledge Building competence. For instance, Yang et al. (2016) use the question, idea, and community categories to analyze Knowledge Forum notes contributed by Grade 11 students. Among them, the question category includes fact-seeking, explanation-seeking, and metacognitive questions. The idea category contains simple claims, elaborations, explanations, and metacognitive statements. The community category is about negotiations of fit and synthesizing notes. Hmelo-Silver and Barrows (2008) categorize the statements generated in medical students' collaborative knowledge building discourse into two major dimensions: collaboration and complexity. The former consists of new ideas, modifications, agreement, disagreement, and "meta," while the latter includes the levels of simple, causally elaborated, and elaborated. Informed by these coding schemes and grounded in our data, we analyzed the types and depth of students classroom-video transcripts and online Knowledge Forum notes. We coded the Knowledge Forum discourse into questions, ideas, information, restatement, integration, regulation and metacognition and their relevant sub-categories.

Little research exists that examines the development of young students' Knowledge Building competence longitudinally and how teachers' design would facilitate this development. Therefore, this study attempts to explore this research gap. The data analyzed include the Knowledge Building Circle recordings and related Knowledge Forum notes of a group of students from grade 1 to grade 3. The research questions guiding this study are:

1. How does students' Knowledge Building competence develop over time at the collective level?
2. How does students' Knowledge Building competence develop over time at the individual level?

Methods

Participants and research context

The study was conducted in a private laboratory school in a major culturally diverse city in North America. The school has a well-established culture and practice of inquiry-based learning and Knowledge Building. A group of 20 students (11 girls) participated in this design-based research from grade 1 to grade 3 (i.e., three years). The students were six to nine years old. The class represented the city's diversity in terms of multi-ethnic, economic, and gender balance. Before commencement, this project was given ethical approval by the school and the university's review board. Consent forms had been signed by the parents/guardians of the participants.

In grade 1, the class aimed to understand the Life Stages of a Butterfly, and the inquiry session lasted for about 40 days. Entering in grade 2, the students mainly worked on the Growth and Changes in Animals and related topics for about 120 days. In grade 3, the students studied Soils in the Environment for about 70 days. The grade 1 teacher had more than 15 years' experience with implementing the Knowledge Building approach in her class. Both the grade 2 and 3 teachers were early in their teaching career, and the Knowledge Building approach was relatively new to them.

From grade 1 to grade 3, the Knowledge Building sessions, including Knowledge Building Circle and Knowledge Forum work, usually took place twice a week and one hour each time. The students began to work in Knowledge Forum at the end of grade 1 as they were developing their computer competences. Entering in grade 2, the students became more capable of working in Knowledge Forum, and therefore, engaged in offline Knowledge Building talks and online Knowledge Forum activities simultaneously so did they in grade 3. Over the three years, various learning opportunities supported the students in researching their questions and sustaining their interest. Some anchors were used to arouse students' interests and curiosity. For instance, in grade 2, a salmon tank was set up in the classroom to hatch salmon eggs. The students went on field trips or invited knowledgeable people to their classrooms to discuss relevant authoritative resources and experiences. For instance, the grade 3 students visited the Humber Arboretum to learn, observe, and experiment soils. The students read relevant books, watched videos, and annotated information for evidence, which also inspired new questions.

The students engaged in monthly metadiscourse to uncover what they had learned, what they still wondered, and how they could improve ideas. In grade 2, questions such as "What have you learned about salmon? How have your ideas about salmon changed? What do you still wonder about salmon? How did you feel during this work?" guided students' monthly metadiscourse. Furthermore, we found that in grade 2, the percentage of explanations and idea integration was relatively low in students' discourse. Therefore, in grade 3, we designed the Knowledge Building sessions to help the students reflect on the distribution of the idea improvement types to identify areas for further work. To support the students to integrate ideas and elaborate on explanations, we also designed peer reading and writing activities, provided scaffolds to support idea synthesis, documented students' oral ideas, and asked the students to write more in-depth notes.

Data collection and analysis

Knowledge Building talks and Knowledge Forum notes were collected from grade 1 to grade 3. The Knowledge Building talks were transcribed verbatim, and each utterance was coded as a unit. Similarly, each Knowledge Forum note was coded as a unit. In grade 1, there were 295 student contributions in total, including utterance and notes, in grade 2, there were 2,188 student records, while in grade 3, there were 1,756 pieces of student contributions. Using an idea improvement coding scheme (Zhu et al., 2019), two researchers coded 432 units, accounting for 19.74% of grade 2 records.

The coding scheme includes seven main categories:
Questions: fact-seeking question, explanation-seeking question, idea-deepening question
Ideas: simple claim, partial explanation, elaborated explanation
Information
Restatement
Integration: simple integration, elaborated integration
Regulation
Metacognition: reflection, student proposal

The agreement between the two researchers was 73.55%. The disagreements between the two researchers were discussed and resolved. The first author coded the remaining data.

Preliminary results and discussions

How does students' Knowledge Building competence develop over time at the collective level?

Figure 1 shows the percentage of different idea improvement types contributed by the participants when they were in grade 1 to grade 3. It shows that over the three years, the students had decreasing levels of simple claims and partial explanations, but increasing levels of idea-deepening questions, elaborated integration, regulation, and student proposals. These results indicate that the cognitive efforts involved in students' contributions increased (e.g., elaborated integration) and the students also took greater epistemic agency (e.g., regulation, proposals). The changes may be related to two reasons. The first one is the development of students' Knowledge Building understanding, which may make them understand that they need contributions such as explanations, elaborated integration, and student proposals in order to advance their community knowledge. The second one is the development of students' Knowledge Building competence, whether due to natural development or the facilitation of the design. Another study (zhu et al., manuscript submitted for publication) with the same dataset suggests that the metadiscourse design helped the students reflect on their learning and propose future research directions.

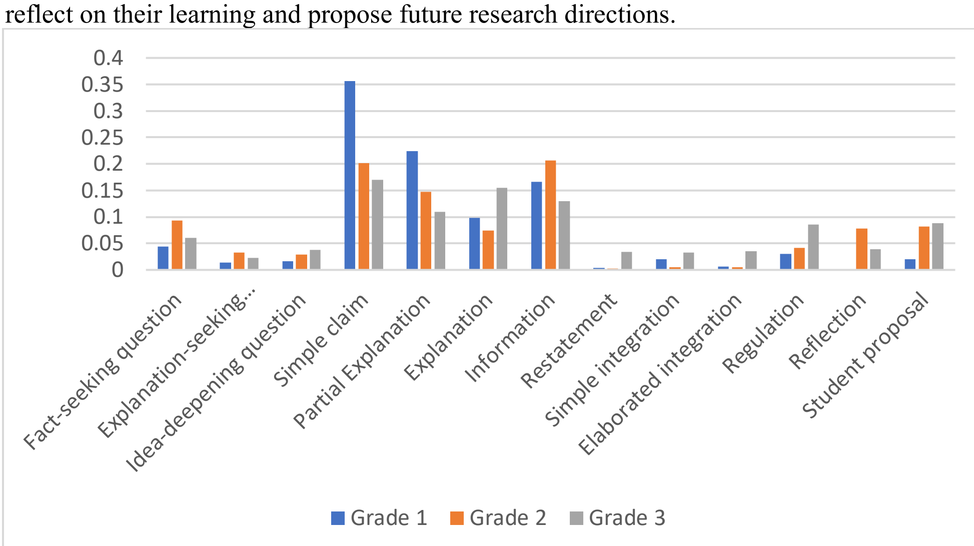

Figure 1. The percentage of different idea improvement types by the students from grade 1 to grade 3

How does students' Knowledge Building competence develop over time at the individual level?

Figure 2 shows the frequency of participants' contributions in Knowledge Building circles and Knowledge Forum. Overall, most of the students contributed much more utterance or notes in grade 2 and grade 3 than they did in grade 1, suggesting that the students had more active Knowledge Building as time unfolded. It should be noted that the Knowledge Building lasted for different durations in different school years, for about 40 days in grade 1, 120 days in grade 2, and 70 days in grade 3. The grade 3 Knowledge Building was interrupted by the Covid-19. But overall, the Knowledge Building inquiry and discourse were more sustainable in grade 2 and grade 3 than that in grade 1, suggesting students' continuous interest in the topics that they inquired.

S1 and S8 had relatively fewer contributions in the three years. Both S1 and S8 only had one contribution which fell in the simple claim category when they were in grade 1. Differently, in grade 2, S1 had 14 contributions, including one explanation-seeking question, two simple claims, three partial explanations, four information, two regulation, one reflection, and one student proposal. S8 had eleven contributions, consisting of two fact-seeking questions, three simple claims, five information, and one regulation. In grade 3, S1 and S8 had three and two contributions respectively. In grade 2, both S1 and S8 contributed most of their utterance in small group activities, in which they built ideal and current salmon habitats and audit the school recycling work. However, in whole class or half class Knowledge Building discourse, they tended to skip their turns of speaking nor did they voluntarily talk much.

S3, S9, S11, and S20 had more contributions than any other participants in each grade. Figure 3 shows the frequency of S9's idea improvement types over three years. S9 had an increasing number of contributions in all subcategories. Further research can qualitatively analyze S9's and other students' (e.g., S18, S20) contributions.

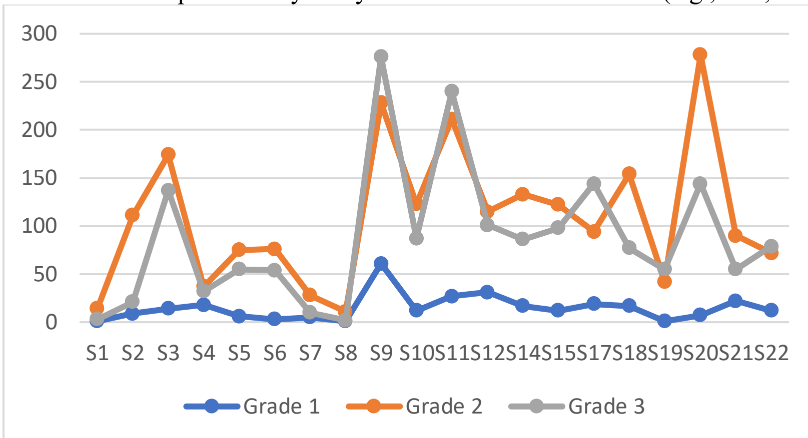

Figure 2. The contribution frequency of different participants from grade 1 to grade 3

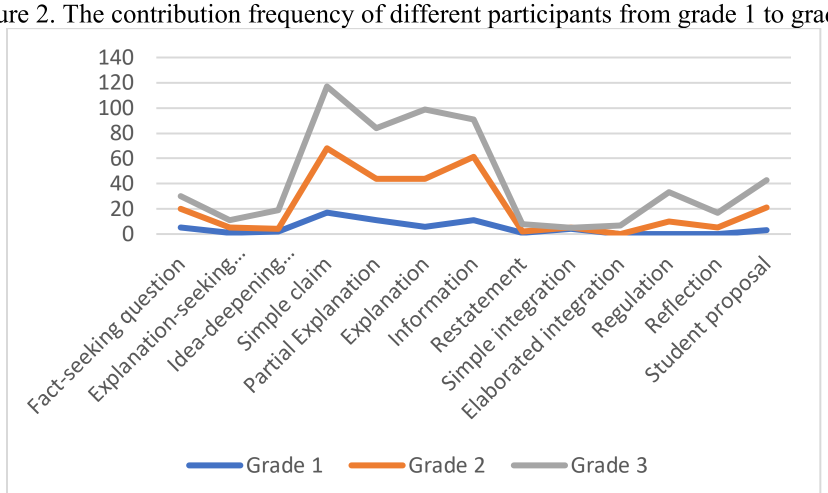

Figure 3. S9's contribution frequency from grade 1 to grade 3

Conclusions and future directions

This ongoing exploratory research examines how young students' Knowledge Building competence develops over the years. The preliminary results suggest that as time unfolded and with appropriate design, students' Knowledge Building competence tended to increase, suggested by the increasing percentage of contributions that require high cognitive efforts. The results also indicate that in general, the participants had greater contributions over the years. Further analysis of the Knowledge Building trajectories of students with different contribution levels is in progress. In addition to S1 and S8, we will provide thick descriptions of representative students who took agency as early as they were in grade 1 and students who gradually gained agency in their Knowledge Building process. We will also analyze in what context the students began to take high-level epistemic agency, and how this affected their following Knowledge Building. In the future, in addition to students' Knowledge Building talks and Knowledge Forum notes, we also plan to collect more types of data, such as students' reflections or interviews to understand students' knowledge building progress - the progress for developing knowledge building competence.

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Posters

How can Knowledge Building (KB) and Knowledge Forum® (KF) Support Plurilingualism in Secondary Science classes?

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Figure 1: Bilingual Scaffolds

How Can Knowledge Building (KB) and Knowledge Forum® (KF) Support Plurilingualism in Secondary Science Classes?

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The Challenge

Students of English as an Additional Language (EAL) new to UK education have to overcome academic language and learning barriers to achieve in the language of instruction. Statistics published in June 2019 by the Department for Education, indicate that a student joining in Year 11 achieves an average attainment score of 23.7, compared to the base line of 46.4 for non-EAL students (Department for Education, 2019). In science classes, EAL students have to acquire a vast specialist academic lexicon in their additional language, and develop sufficiently high levels of scientific understanding to be able to evaluate and solve complex problems collaboratively (Cummins, 2000), (Swanson et al., 2014). Equally, the barriers to participation in collaborative problem-solving they face mean that the communities of learning they join do not benefit from the ideas they could contribute.

Plurilingualism

Growing linguistic diversity worldwide has led to calls, notably from the Council of Europe, to promote plurilingualism and challenge "the squandering of classroom, personal, community, and national linguistic and intellectual resources within the mainstream classroom" (Cummins, 2005, p. 585). By recognising students' linguistic repertoires, educators can help to promote "plurilingual language practices, and the transfer of skills between languages" (Stille & Cummins, 2013, p. 613). Plurilingual pedagogy requires a learning environment which can leverage the potential of a complex yet rich linguistic landscape.

Knowledge Building and Knowledge Forum

KB leverages complex learning environments since it enables students to collaboratively "build coherent knowledge out of fragmentary information coming from multiple sources" (Scardamalia & Bereiter, 2014, p. 402) and the KF® software which supports KB has affordances which make collaborative knowledge building more accessible to linguistically-diverse students, providing an example of how "access to digital media enables teachers and students to foster plurilingualism through multiple modes of representation that extend beyond the boundaries of linear one-dimensional print" (Stille & Cummins, 2013, p. 632).

Knowledge Building Principles for Plurilingualism

GREATER DIVERSITY OF REAL IDEAS FOR COMMUNITY KNOWLEDGE

Facilitating access for EAL students to KB communities means valuing contributions from different perspectives, enriching the pool of ideas in pursuit of real-world understanding (Bereiter & Scardamalia, 2010).

FROM IMPROVABLE IDEAS TO RISE ABOVE

Access to knowledge building with authoritative sources means the ideas of all can be improved. Rise-above raises meta-cognitive and metalinguistic awareness as the community monitors how ideas evolve (Bereiter et al., 2016).

EPISTEMIC AGENCY FOR ALL DEMOCRATISES KNOWLEDGE

KF® offers linguistically-diverse students agency to build their technical knowledge in collaboration with their peers, simultaneously building linguistic knowledge and improving outcomes (Scardamalia, 2002).

SYMMETRIC KNOWLEDGE ADVANCEMENT

KF® makes individual thinking visible to the whole community, creating a virtual dialogic space for collective agency where all linguistic groups gain knowledge from each other.

My PhD Project

MY GOAL

I aim to use a design-based research (DBR) methodology to investigate how KB and KF® can provide a plurilingual dialogic space for science learning and language development in the UK where all the intellectual resources of a multilingual student can be leveraged.This project contributes to a readjustment of attitudes towards the linguistic repertoires and competences of linguistically-diverse students, strengthens recognition of dynamic plurilingual repertoires, widens participation in the creation of knowledge, and supports sustainable linguistic diversity and social justice.

WORK IN PROGRESS

My exploration of KF® has shown that, in addition to 'multilingual notes' and 'enable translation', it is possible to create bilingual scaffolds. I have created and tested a set of bilingual scaffolds (See Figure 1).

To improve my understanding of how the multilingual features of KF® are being used, I am gathering information from members of the KBI community.

I am building a map of conjectures and plan a three-cycle structure for my DBR framework.

NEXT STEPS

I will build on the information gathered, and refine my DBR framework, by running a pilot project.

The pilot project will be set in the context of an extra-curricular STEM club which includes linguistically-diverse secondary students in the UK, who will use KF® with sets of bilingual scaffolds relevant to the languages in the class. I hope to involve the students in creating the translations for the bilingual scaffolds. The goal of the pilot project will be to explore an A-level Biology topic.

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Let's observe our school forest life!

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Zones of Collective Knowledge Building

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INTRODUCTION

The Knowledge Building is a theoretical framework that recognizes and develops the student's capacity to improve ideas in an educational community. It is important to take advantage of the **collective cognitive responsibility (CCR)** for the proper funtioning of the Knowledge Building communities (KBC). Collective cognitive responsibility assumes that all members are responsible for the construction of knowledge which is created in a community (**Scardamalia, 2002**).

The CCR does not only depend on historical individual and group characteristics of the members. CCR is also modulated by factors that characterize the implementation of the KB theory. In others words, the teacher can be an agent who facilitates the CCR implementing **Knowledge Building sequences** (e.g. see Gutiérrez-Braojos 2020). In this way, students can follow **progressive knowledge building trajectories.** And with this, participate in zones of collective knowledge building with greater impact (for example, see Gutiérrez-Braojos et al., 2019, under review).

OBJECTIVES

In this study we explore CCR and trajectories of students. The aims of the study are as follows:

A1: Exploring the equidistribution of the builders´ impact.
A2: Identifying the percentage of members in each impact zone through the discussion topics.
A3: Analyzing individual flow through impact zones and discussion topics.
A4. Understanding individual trajectories from presage variables.

METHOD

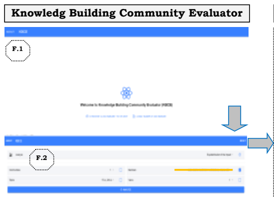
The participants were 23 university students enrolled in the educational research subject of the second year of the Education degree. The KB implementation experience lasted 3 months. This implementation was carried out under an educational hybrid model (face-to-face and online) supported by the Knowldge Forum platform (Scardamalia, 2004). For this study, **Promising Ideas Tool** (Chen et al., 2015) were used to extract citation. The **Knowledge Building Community Evaluator tool, KBCE** (Gutiérrez-Braojos et al. paper in elaboration) were applied to analyze **impact builders, <u>equidistribution of the impact, impact zones, and flow through impact zones</u>** <u>across three of 2 discussion topics: i) Action-Research Foundations (ARF), ii) Action-Research Implementation (ARI)</u>. In addtion, in order to explore **individual trajectories**, several questionnaires were applied to analyze presage variables effects on CCR. The variables and mesarures are the following:

1. **Prior knowledge and knowledge achieved tests** consisting of 10 items regarding a Action-Research practical case based on the official guide of the subject.
2. **Endogenous perceived instrumentality** (Husman et al., 2012): 4 items with 10-point Likert Scale.
3. **Efficacy Beliefs for Conceptual Change**: (17 items with 10-points Likert Scale (Scakes et al., 2012), and 5 items 10-point ad hoc questionnaire to analyze beliefs for improving ideas (Gutiérrez-Braojos based on Martin & Rubin, 1995) .

In order not to be invasive, a single item with 10-points Likert Scale has been used for variables that have shown to be important in collaborative work at educational levels: 4. **Attitude** (passive vs. active) towards the action research subject; 5. Perceived **difficulty** of the subject; 6. Attitudes towards the use of **technologies during learning experiences**.

RESULTS:MACRO-LEVEL

Knowledg Building Community Evaluator



KBCE presents different analysis tools (Figure 1, 2, Gutiérrez-Braojos et al., paper in elaboration). In this study, we have applied the following tools: i) equidistribution of impact; ii) network recognition; iii) impact zones; iv) flow through impact zones.

A1: Exploring the equidistribution of the builders´ impact

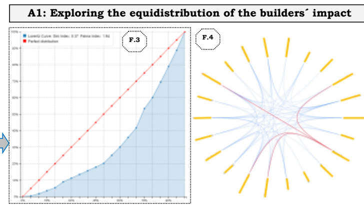
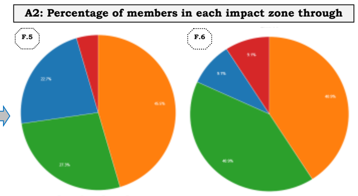


Figure 3 shows the general equidistribution of buidlers´impact (blue line or Lorenz curve), ideal distribution (red line), Gini and Palma index. Gini value shows a moderate-low inequality in the distribution of the recognition that each author receives for their ideas. Palma index indicates that students who are located in the first decile of recognition for their ideas, obtain almost twice as many citations than members located in the last 4 deciles of impact. Figure 4 shows network recognition bewteen members (Members' names were covered with yellow lines due to ethical reasons).

A2: Percentage of members in each impact zone through



The impact zones indicate that there is an improvement in topic 2 (ARI) compared to the initial topic (ARF). In particular, a decrease in the percentage of members is observed in the periphery and transitory zone. And there is an increase in the percentage of members in zones (continuous and core) that show high recognition by the community (See Figure 5 "ARF", and Figure 6 "ARI").

RESULTS:MICRO-LEVEL

A4: Presage variables

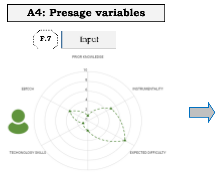
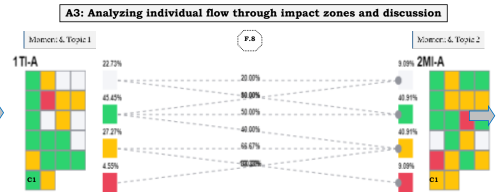


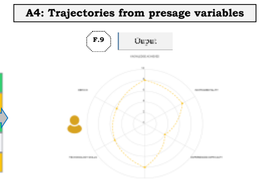
Figure 7 shows a case (Case1) which have been intentionally selected to illustrate possible individual trajectories in communities based on KB sequences. This student manifests in the questionnaires with presage variables low scores that predict poor performance and performance in this subject.
* Note the colors do not represent the same zones as figures 5 and 6.

A3: Analyzing individual flow through impact zones and discussion



This student shows an improvement in his trajectory, he has gone from being in a transitory zone of impact to a continuous zone (Figure 8).
These results should help the student to improve his beliefs of self-efficacy and obtain a better performance in the final test of the subject.
* Note Other cases can be analyzed to understand the trajectories of the students.

A4: Trajectories from presage variables



This student manifests higher scores in his beliefs of self-efficacy and knowledge in the subject (Figure 9) than in presage variables (Input phase).

CONCLUSIONS

In this poster we proposed to map the individual trajectories from zones of CCR using KBCE tool. For us, CCR and KB Zones are substantive, that is, they are relative and are defined according to the internal dynamics in each community. We use two levels of analysis: macro and micro. In addition, the analysis was carried out in four moments: Input (presage variables), Moment and Topic 1 (Foundations of AR), Moment and Topic 2 (Implementation of AR) and output (product variables).

A1 and A2: Macro-analysis shows a relative equality of the members regarding the recognition received from their peers because of their ideas. Although it could be observed that students located in the peripheral zone show a number of recognized ideas much less than the students who form the core (Palma index). Therefore, teacher should try to empower students located in the last four deciles to reduce the difference between students located in these zones. Micro level could be useful for identify students situated in the peripheral zone.

A3 and A4: Micro analysis indicates the individual flow through of the recognition zones in which they are classified by each topic of discussion. Thus, students have been classified according to 4 impact zones extracted from the distribution of citations that each member get from their peers (lorenz curve). In addition, we have analyzed presage and product variables in the students. A comparison between the input and the output indicates that: <u>our knowlege building sequences could be a relevant variable in order to modulate variations from the results of the presage variable to the product variable</u>.

In conclusions: I) we can say that an acceptable CCR has been observed. ii) This approach and KBCE tool have been useful to understand community and individual dynamics, both interdependent on each other.

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Intelligent Support for Knowledge Building Across Web Spaces

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Problem

Many tools, such as Knowledge Forum (KF) and Hypothes.is, are great for facilitating student dialogues. While KF provides specialized support for knowledge-building discourse, Hypothes.is as a web annotation technology allows students to make sense of web materials collaboratively. However, these platforms operate independently and are not connected to support cohesive knowledge work by students. Often times, student work is scattered across different spaces, requiring substantial efforts from students to stay organized. Given students are working with a broad range of web information, they need more support to build knowledge effectively across web spaces.

Research and Development Goals

This work builds on the IdeaMagnets project that allows students to import their web annotations from Hypothes.is into KF to continually develop their ideas (Chen et al., 2020). Our goal is to devise intelligent support for the process of connecting web annotations with student writing in KF. We will achieve this goal by:

1. Conducting network-based text mining on students' KF and Hypothes.is contributions
2. Suggesting search terms that students can use to search their Hypothes.is annotations in order to bridge knowledge gaps in their KF discourse

Results

We analyzed data from a Grade 9 science class that used both *KF* and *Hypothes.is* to facilitate group knowledge building. To provide intelligent support for idea development, students' KF notes were imported into InfraNodus – a web-based software tool that generates insights into the text based on analysis of a cooccurrence network of terms (Paranyushkin, 2019). Structural gaps can be identified based on the analysis, suggesting terms students could use to search their Hypothes.is annotations in order to close the identified gaps. For example, as illustrated in Figure 1, the class' KF discourse currently covers two clusters of terms related to greenhouse gases but these two clusters are weakly connected. Using this insight, a student can search their Hypothes.is annotations via the IdeaMagnets tool to identify external web information that may help the class bridge the gap. The student can also use the extracted topics and terms to further develop ideas, discern idea connections, and create rise-above ideas.

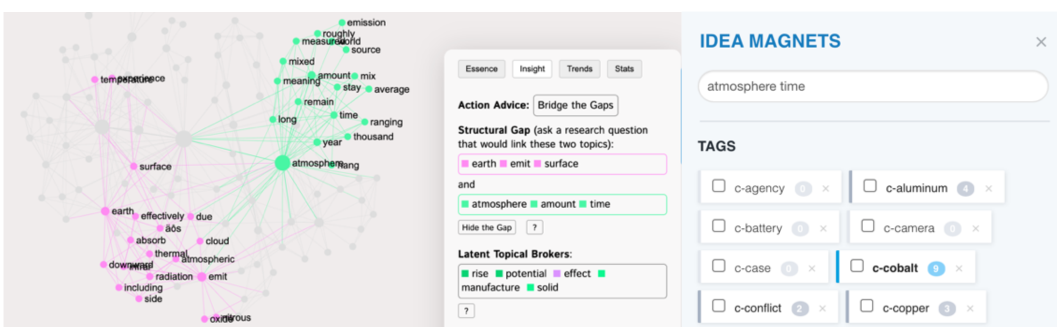

Figure 1. (a) Text analysis showing a structural gap. (b) Using search terms in IdeaMagnets to bridge the gap.

Significance & Next Steps

The present study aims to build intelligent support to harness system log data to scaffold continual development of student ideas based on rich information. Our next steps are to continue exploring features of InfraNodus, and text network analysis in general, to support students' knowledge building across web spaces. This work will inform future prototyping within the Knowledge Forum environment.

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Knowledge Building International Project on Gender Equality: "Knowing our Roles, sharing our responsibilities"

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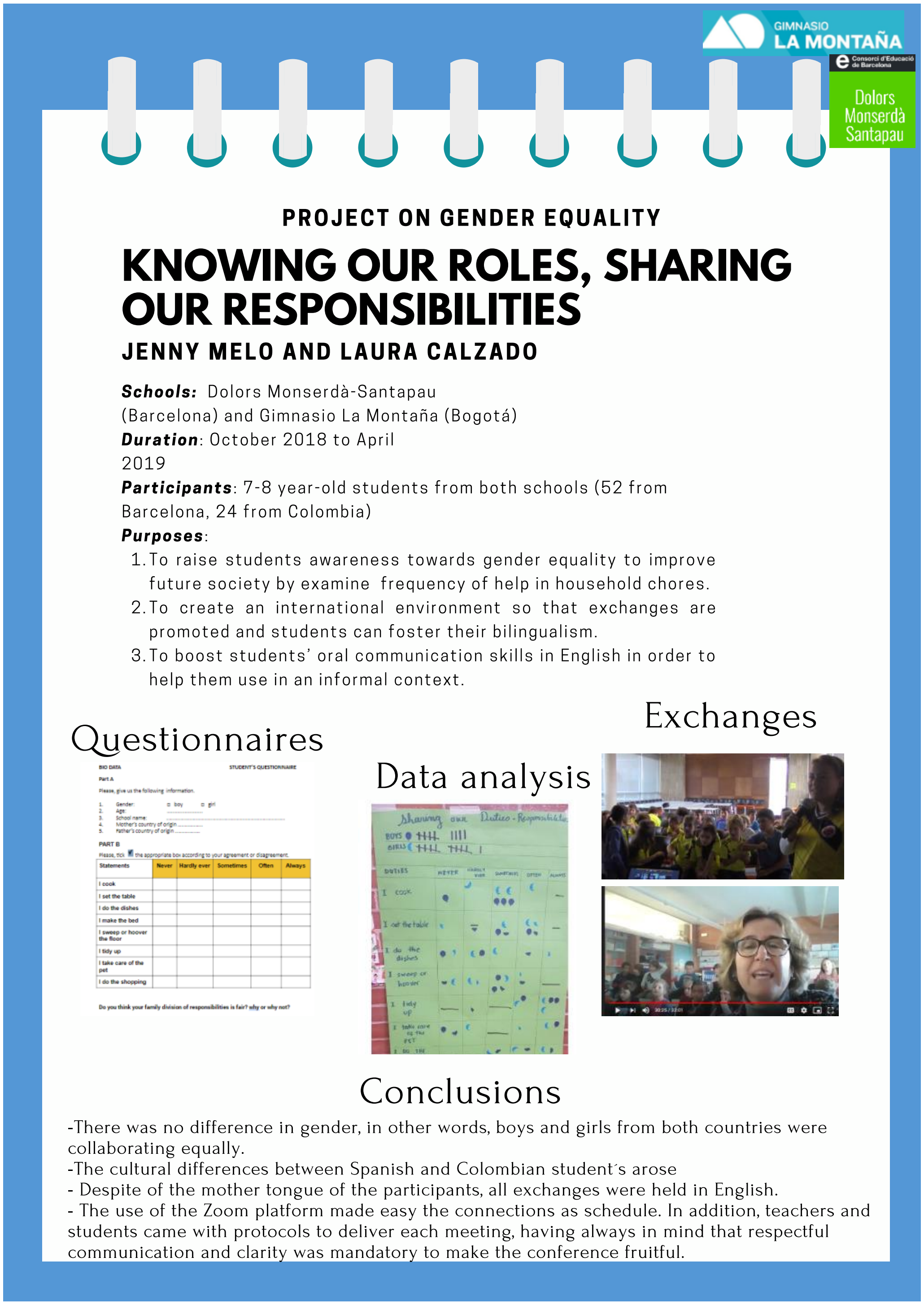

Cultivating Knowledge Building Culture in an ESL Writing Class

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Cultivating Knowledge Building Culture in an ESL Writing Class

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Introduction

- English language learners (ELLs) are more sensitive to the views of others due to the lack of confidence in their language abilities. The feelings of stress and anxiety inhibit their language learning and performance abilities (Tanveer, 2007).
- In the absence of guidance directing students to build upon peer responses, they will often default to posting a personal response (Leafstedt and Hannans, 2020).
- A design based research (DBR) methodology (Anderson & Shattuck, 2012) was used in this exploratory study with two interventions implemented, inspired to KB principles, to cultivate a relaxing and supportive environment for students to form, share and improve their authentic ideas.
- The study is not attempting "full-blown" KB, but to zero in on "real ideas, authentic problems" and "knowledge building discourse" as starting point for build KB culture.

Methodology

- **Participants:** Students involved in this study were all ELLs from an internationalized K12 school in Dongguan, China. The data have been collected from the students from 4 different classes, with three 40-minute sessions for each class, of two subsequent academic years:

➢ 2019-2020:

G4-A: 14 students (7 boys and 7 girls); Lexile range: Highest: 545L-695L; Lowest: BR240L-BR90L; Median: 183L-333L

G4-B: 14 students (8 boys and 6 girls); Lexile range: Highest: 505L-655L; Lowest: BR80L-70L; Median: 225L-375L.

G5: 17 students (8 boys and 9 girls); Lexile range: Highest: 950L-1100L; Lowest BR20L-130L; Median: 605L-755L.

➢ 2020-2021:

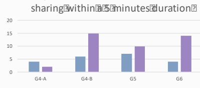
G6: 15 students (6 girls and 9 boys). Lexile range: Highest: 750L-900L; Lowest: 0L-150L; Median: 405L-555L.

KB Strategy Intervention 1: Free Turn-taking

- **Procedure:** FTT (Free Turn-taking) indicates a different sharing guideline from a regular primary or middle school class norm. Students were asked not to raise their hands for a turn to talk, mimicking real life situations. Instead, they voluntarily took turns when the previous student finished sharing. The teacher majorly acted as a recorder for students' ideas. The guideline was adopted twice each class.

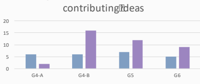
Intervention 1 Result

Figure 1. Number of intentions for sharing within 5 minutes duration



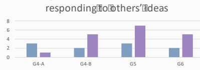
- Figure 1 showed the number of students who showed intention on sharing (through counting the times when students were attempting for a turn) increased since adopting FTT guideline, except for G4-A.

Figure 2. Number of students contributing ideas



- Figure 2 showed the number of students who actually contributed ideas also increased with FTT guideline, except for G4-A.

Figure 3. Number of students responding to others' ideas



- Figure 3 showed the number of students who built on others' ideas has increased with FTT, except for G4-A.

Conclusion and Implication

- The FTT strategy for cultivating a relaxing and comfortable environment positively impact ELLs to form, share and improve their authentic ideas.
- Students from a relatively strictly managed or traditional learning environment may need more time to get used to FTT.
- The ELL friendly scaffolds, rooted from KB principle "knowledge building discourse", allow ELLs to advance their abilities in forming persuasive arguments.
- Studies on bilinguals suggest that a foreign language plays an important and unconscious role in thinking (Jiang, Ouyang, & Liu, 2016). In order to encourage ideas sharing in a second language, it is crucial to ensure the English language learners are feeling relaxed and willing to take more risks, such as voicing half-baked notions and giving and receiving criticism.

- **Educational setting:** Prior to producing a final written work, the students attended classes that were designed to equip them with notions and tools for a strong opinion essay. The goals of the classes were 1) students are able to clearly express their opinions; 2) students understand the importance of including reasons and examples, as well as counter-claims for the use of making their opinions stronger. With the interventions, students were expected to achieve the goals through their own improved ideas.
- **Observed Variables:**
  G4-A is a tidy classroom with strict rules managed by their homeroom teachers.
  G4-B is a messy classroom without strict class rules.
  G5 and G6 are classrooms with a fair amount of rules.
- **Data collection methods:**
  Observations (in class, recorded class video)
  Students' artifacts (KB scaffolds, essay paper)
  Teacher reflective journal

KB Strategy Intervention 2: ELL Friendly Scaffolds

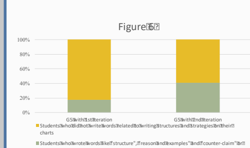
Knowledge Building scaffolds can easily be modified to support students' progressive discourse in different content areas and in different levels of education (Zhang et al., 2011).

- **Procedure:** Students first worked individually then as a group with their KB scaffolds charts. When finished, they shared their ideas to the whole class. This intervention has been adopted in all homerooms; however, G5 was the only class involved in both iterations.
- **Iterations:** The strategy was implemented in two iterations.

Figure 4. 1st iteration

Figure 5. 2nd iteration

Intervention 2 Result



- Phrases such as "one clear opinion", "using more facts", "using more examples" and "other people have different opinions" appearing on the "changes to make" sections of students' scaffolds charts were used as indicators for students' abilities to form strong opinions. Figure 6 showed that, with the simplified scaffolds, about 24% more students were able to improve their previous method on supporting their opinions.

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Assessment in Knowledge Building: How to apply written feedback strategy to guide Key Stage 1 students keeping focus on the targeted topic throughout cross curricular study?

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Keyword: Written feedback, knowledge building, assessment, cross curricular

1. Introduction

1.1 Statement of the Issue:

Nowadays, as we value more on students' voice and creativity (Bereiter & Scardamalia, 2010), Knowledge Building pedagogy has come into the spotlight in the education area internationally. The idea of Knowledge Building is to bring notes, which contain deep embeddedness, and views of different people together to create a community of knowledge (Scardamalia, 2002). While people are making connections between one idea and another, new thoughts could be emerged, and the newly created knowledge can contribute to another creation of knowledge, which is the dynamic that the 21st century has been depended on (Homer-Dixon, 2006). To help students in primary school to engage in Knowledge Building is difficult as children could hardly contribute to the community of knowledge with limited factual knowledge and too much instructions from teacher. However, students in primary school do need certain guidance from others to help them focusing on one topic and digging deeper into that area. Assessment for learning (AfL) would be a perfect tool for teachers to assist primary students in Knowledge Building. AfL is known as formative assessment, which focus solely on the process that learners are making instead of the final result (Isaacs et al., 2013; Lambert & Lines, 2000). One of the most valuable aspects of AfL is the feedback provided by participants, including both teacher and students (McDowell et al., 2010). As it is claimed by Bramwell-Lalor and Rainford (2016), feedback could lead to a more positive attitude and a higher responsive rate to discussion. Discussion is one of the important elements in Knowledge Building as it could inspire the process of linking ideas and creating new knowledge (Scardamalia, 2002). To engage students in the active formative assessment could be one of the practical solutions to Scardamlia's idea of moving ideas to the center of a classroom instead of activities (2002).

1.2 Real Life Situation:

I valued feedback in my own classroom, especially written feedback. I had two different class. In my primary one Math lesson, I marked students' homework and gave feedback every time. Though there was no guaranty that students were going to read and respond considering their young age, for one of my class, more than half of the students responded to the comment and questions I wrote. For example, a student had all the answers right for two-digit addition question but did not show the steps of doing the work. I praised his effort and challenged him with a further question (one three-digit number adding a two-digit number). He answered my questions with expended form and he got the answer correctly. From this dialogue, I could see he has mastered the concept of number and understand the idea of addition. Furthermore, by answering my questions, he made connection between the method of using expended form and calculation skills. Therefore, he made further development in his knowledge building. However, in the other class, I had less responding rate, I found that students are still straggling with two-digit number addition and I had a hard time finding out the reasons. Therefore, written dialogues visualized the progress students were making, and helped me identifying the ideas they have in mind. With this information, I could better guide students to build their community of knowledge. Hence, it is intriguing to find out how to apply written feedback strategy to guide Key Stage 1 students keeping focus on the targeted topic throughout cross curricular study.

1.3 Research question:

How to apply written feedback strategy to guide Key Stage 1 students keeping focus on the targeted topic throughout cross curricular study?

1.4 Major Goals:

1. To stress on the concerns of practical problems of implementing Knowledge Building in primary classroom through AfL.
2. To introduce assessment for learning in the context of Knowledge Building and underline the advantage of using AfL.
3. To build up ideas on the ways teacher could use AfL in classroom to assist students building the community of knowledge.

2. Methodology

2.1 Preparation

For the preparation stage, observation and interviews is being carried out. The main aim of the pre-research stage is to help narrowing the focus of the following research from written feedback to 1-3 specific strategies. Corresponding with the research, the main goal is to find out written feedback strategies that have top three response rate. The higher the rate is, the more meaningful the strategy could be to Knowledge Building. To better serve the aim, a mixed method research has been designed. This perpetration stage should be 35-40 weeks depending on the frequency of cross curricular activities.

All the participants are grade one, and they come from the same class of an international primary school. Observations focus on different written feedback strategies that has been used throughout cross curricular activities, and the number of responses that students give. The interviews focus on the purpose of the designed feedback strategies. The interviewee is the classroom teacher who implements all the activities.

For data collection, all different feedback strategies that will be used in the classroom will be noted down, and the number of times the strategies have been used will be written down in the observation note. Also, the number of responses each strategy gets will be counted and noted down. For interviews, semi-structured interviews will be conducted after each cross curricular activity finished. Transcripts will be collected.

Data from observations will be transferred into percentage showing students' respond rate to each feedback strategy. Data from interview will be analyzed alongside the percentage of the respond rate.

At the end of the preparation stage, three feedback strategies should be selected for the action research.

2.2 Participants

This research is going to an action research. All of the participants will be primary one student in my class, which should be around 20 students. Ethic forms will be signed by both parents and students before the research take place. The time period of each round of the action research should be 16 to 20 weeks.

2.3 Data collection and analysis

All the written feedback will be collected and cataloged based on the topic of the cross curricular activities. The written feedback includes feedback for homework, quizzes, activities, tasks and peer evaluation. These data will be stored in a safe laptop with password protection, and the original data will be kept for two years after the researcher is finished.

2.3 Clear Description of Audience Engagement:

In this session, we invite all the participants to contribute to the area of the usage of assessment, and build up a basic community of knowledge under this topic. This session will consist of three sections:
1. A brief presentation on the advantages of engaging assessment for learning into the process of Knowledge Building for students in primary school.
2. Group discussion on the usage on AfL that could be implemented into primary classroom with efficiency under the context of Knowledge Building.
3. Collecting and building up ideas to produce a summary for the KBSI database.

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The Method of Locating Teaching Starting Point in Knowledge Building

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