Fostering College Students' Design Thinking via Knowledge-Building Activities

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Abstract

This study used online activities in a knowledge-building environment to foster design thinking skill. Participants were 38 college students randomly assigned to eight groups in an "Introduction to Living Technology" course at a Taiwanese university. Each group used the Knowledge Forum-a computer-supported collaborative knowledge-building environment-to design a product of their choice. Data analysis focused on online knowledge-building activities and their effects on students' design thinking. In general, knowledge-building activities facilitated students' capacity for design thinking as a group. Specifically, the extent to which groups sustained online engagement and increased their group's knowledge had a major impact on their design performance. Ways of applying knowledge-building principles to foster effective design processes are discussed.

Keywords: design thinking, knowledge building, Knowledge Forum

Introduction

Design thinking is recognized as an important competency that is essential for knowledge workers in knowledge-intensive society (Bereiter & Scardamalia, 2014; Koh, Chai, Benjamin, & Hong, 2015; Scheer, Noweski, & Meinel, 2012). An important strand of research in design thinking is to foster students' design thinking so that they can be effective knowledge workers. This includes research on providing more effective and productive online learning environments. To date there have been relatively few studies dedicated to improving researchers' and educators' understanding on how to foster students' design skills using online learning environments or the design of pedagogically effective online activities (Taheri & Meinel, 2015; Taheri, Unterholzer, & Meinel, 2016). The purpose of this study was therefore to investigate the effects of a computer-supported knowledge-building environment called Knowledge Forum (KF) on students' design thinking, with a particular emphasis on the role of online activities in shaping students' design thinking.

Literature Review

Design thinking

Design thinking is defined as a cognitive activity or strategy that is used to solve complex problems by coming up with an optimal solution or product (Carroll, Goldman, Britos, Koh, Royalty,& Hornstein, 2010; Noweski, Scheer, Büttner, von Thienen, Erdmann, & Meinel, 2012). As a problem-solving process, design thinking is usually represented as a cycle that starts with empathic observation of an ill-defined problem (Buchanan, 1992). To help learners develop their design-thinking capacity, Norman (2013) extended the original concept of a "double-diamond design process model" (British Design Council, 2005) and proposed a revised "double-diamond model." This revised model consists of a problem space and a solution space, involves four essential tasks: observation, synthesis, ideation and prototype construction (Plattner, 2010). Observation is fundamental to understanding what and how people behave in the world. Synthesis coordinates the insights gained from observation into a specific plan in order to improve the framing of the problem. Ideation subsequently shifts the design work from identifying problems to the creative phase in which designers work creatively with various ideas in an iterative, exploratory and chaotic process (Braha & Reich, 2003). Design thinkers have to be able to tolerate the ambiguity inherent in intractable problems. Finally, ideas are put into practice in the form of construction of a prototype or product with real-world application.

Empirically, studies have shown that learning activities that involve design thinking are usually more engaging (Noweski et al., 2012; Goldman, Kabayadondo, Royalty, Carroll, & Roth, 2014). However, because most studies of design thinking have been based on face-to-face learning activities (Carroll et al., 2010; Kolodner, Gray, & Fasse, 2003; Scheer et al., 2012), it is unclear if the findings can be applied to online learning environments where technology is used extensively to enhance student learning (Carroll et al., 2010). Moreover, most evaluations of design thinking relate to the assessment of products rather than processes (Seidel & Fixson, 2013). From a process perspective, educational research is concerned with the process of equipping students with competences such as cognitive and social skills (Todd, 1999), meta-cognitive skills (Carroll et al., 2010; Scheer et al., 2012), creative problem solving skills (Barron, 2006; Hmelo, Holton, & Kolodner, 2000), and even design-thinking capability (Rauth, Köppen, Jobst, & Meinel, 2010). It is thus necessary to examine design thinking in an online learning environment from a process perspective.

Knowledge building environment

The KF is a computer-supported, collaborative knowledge-building environment designed to facilitate the three activities that are central to a knowledge-building community: community awareness, contribution of ideas, and building on ideas. Knowledge-building principles are often employed as scaffolds to help students progress from engagement activities (i.e. community awareness, contribution of ideas and building on ideas) to sustained idea improvement for quality knowledge advancement (see Chen & Hong, 2016, for a review). This study made particular use of two knowledge-building principles. The first is "community knowledge, collective responsibility", which requires students to transform their individual learning process into a collaborative effort to advance knowledge (Zhang, Scardamalia, Reeve, & Messina, 2009). This means that students need to contribute ideas to the whole community rather than working purely for personal knowledge acquisition (Hong & Sullivan, 2009). The other principle is that of "improvable ideas" which guide students to engage in idea-centered collaboration with an aim to facilitate sustained idea development. Idea improvement is one of the factors that distinguishes knowledge building from other forms of constructivist pedagogy, e.g. project- or problem-based learning (Scardamalia, 2002; Scardamalia & Bereiter, 2003).

Studies of KF show that it serves as a platform for collaborative activities that enhance students' ability to reflect collectively (Paavola & Hakkarainen, 2005; Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010). These earlier studies have demonstrated the value of KF as a knowledge-building environment in which students can develop their design ideas. Nonetheless, no study has focused on the relationship between groups' collaborative activities and their design-thinking performance in online knowledge-building environments. In this study, we used the knowledge building principles to guide students' knowledge-building work in KF in the hope that doing so would enhance their design thinking.

Facilitating Design Thinking through Knowledge Building

Bereiter and Scardamalia (2006) advocated that the epistemic framing of knowledge building is design mode of thinking, which focus on the usefulness of ideas rather than its true value. Similarly, design thinking is concerned with the practical value and usefulness of idea and the solution given a desirable situation (Tsai, Chai, Wong, Hong, & Tan, 2013). It is thus posited that engaging students in a knowledge-building environment is conducive to design thinking. The similarity of knowledge building and design thinking: first, a knowledge-building environment is designed to facilitate the development of high-level thinking skills such as reflective thinking (e.g. see So, Seah, & Toh-Heng, 2010) and creative thinking (e.g. see Lin, Chang, Lin, & Hong, 2017) and design thinking is an important type of high-level thinking. Second, knowledge building is an emergent, self-organizing process of sustained idea improvement (Hong & Sullivan, 2009) which is compatible with the iterative design thinking process that involves improving a design through the embodiment of invisible ideas. Third, knowledge building provides some overall, abstract, top-level, guiding principles (Scardamalia, 2002) for online behavior and these principles can be a useful guide for concrete, task-oriented design activities. Fourth, a knowledge-building environment is designed to enable sustained improvement of ideas; which the four design-thinking tasks (observing, synthesizing, generating ideas, and creating prototypes) would benefit creative works with design ideas are iterative. Finally, the goal of knowledge building is to advance knowledge and the goal of design thinking to design a product; the two goals seem complementary in that advancement of knowledge should lead to better product design.

This Study

The aim of this study was to address the pedagogical challenge that students' design-thinking capability can be fostered by actively engaging them in a knowledge-building environment. The specific research questions addressed by this study were: (1) How does a knowledge-building environment facilitate the development of design-thinking skills? (2) How is the participants' online KF activities related to its design-thinking performance? (3) How do online KF activities advance groups' knowledge and thus develop their design-thinking capability?

Method

The participants were 38 undergraduate students aged 18 to 22 years, from a national university in Taiwan. They enrolled in an elective course titled "Introduction to Living Technology". At the start of the course the participants were randomly assigned to eight small groups (G1 to G8) with four or five members each. The groups were given advice on choosing a project topic. The data of this research was based on a computer-supported, collaborative knowledge-building environment called KF that was used to engage students in self-directed inquiry. The course lasted for one 18-week semester. The main goal of the online part of the course was to help students develop design-thinking skills through knowledge-building activities and the course requirement was for the groups to design a living technology product. The instructor was an experienced knowledge-building practitioner and his role for on online part was to set up and manage the online learning environment and provide administrative help when necessary.

Analysis of Principle-Based KF Activities

The online knowledge work was guided by two knowledge-building principles: "community knowledge, collective responsibility" and "improvable ideas". The first principle states that participants should work collectively to advance the group's knowledge. To do this they need to raise their community awareness by reading each other's notes. The participants need to contribute their ideas to the community in the form of notes and collaborate actively with other group members by building on each other's ideas in KF. These three main KF activities essentially reflect the extent of students' online activity engagement.

The second principle, "improvable ideas", asserts that ideas are improvable and that collective advancement of knowledge depends on sustained, creative work with ideas as a group. More importantly, however, they also need to monitor the quality of ideas in the notes continuously, in order to determine whether there is sustained idea improvement indicating an advance in knowledge. The important point is that it is the production and refinement of ideas (i.e. knowledge advancement activities) that leads to the evolution of group knowledge. We analyzed students' collective knowledge advancement in the online community by coding their built-on (i.e., connected) notes in the KF database using a revised version of Bloom's taxonomy (see Anderson, Krathwohl, & Bloom, 2001). A knowledge advancement activity here is defined as a cognitive activity intended to deepen understanding of an issue (Jansen, Booth, & Smith, 2009) and this intention is made explicit during online discussion by use of a relevant verb. Using six cognitive levels from remembering to creating, along with exemplary verbal concepts to indicate knowledge advancing efforts (such as interpreting, designing, etc.), a score of 1 to 6 was assigned. Two researchers independently coded all the data and Cohen's kappa coefficient computed was 0.87 ($p < 0.001$).

Analysis of Design-Thinking Skills

During the design process, students were introduced to the four design-thinking tasks to help them design their product. Analyses focusing on these four tasks as reflected in their discussion in KF help to answer the first research question. This study further shows the detailed coding scheme employed from “d. school” (Plattner, 2010) to classify activities in terms of the four main design-thinking tasks. Using ideas as the unit of analysis, two researchers independently coded the data into ideas, and the Cohen's kappa coefficient for inter-coder reliability was 0.82 ($p < .001$). Next, ideas were sorted according to the time they were generated and the skill to which they related (observation, synthesis, idea generation and prototype creation). Two additional researchers independently assigned the coded data into the above four skill categories, with Cohen's kappa coefficient, for inter-coder reliability computed to be 0.90 ($p < .001$).

Results

Overall Design-Thinking Performance and Process

We used sequential analysis to deepen our understanding of how students’ activities mapped to the design cycle and the four design-thinking tasks. The results indicate that students were able to complete all four design-thinking tasks required in a typical design cycle. The number of times each design-thinking skill was used in the process was as follows, observation: 116; synthesis: 108; idea generation: 251; prototype creation: 103. The findings show that working repeatedly on the same task for each of the four design-thinking tasks were statistically significant, indicating that students were deeply engaged in each of the four design-thinking tasks. In contrast, transitions from one task to a succeeding task in a design cycle (e.g., from observation to synthesis) were not statistically significant, implying that it can be challenging for groups to smoothly move on to next design-thinking task given limited time frame. The findings imply that just-in-time scaffolds may be needed to help students focus their convergent thinking skills on moving from one design-thinking task to another. It is also important to consider the implications of these results for the design of knowledge-building environments. In the next section, we examine how KF activities are related to design-thinking skills in order to gain an understanding of how to improve students’ design thinking.

Relationship Between KF Activities and the Design-Thinking Process

In this study an online knowledge-building environment, KF, was used to support four design-thinking tasks and so students’ online activities were important indicators of their design thinking. As discussed above, there are three main KF activities: contributing notes, reading notes and building on notes. In total the 38 participants contributed 399 notes (M = 10.5, SD = 7.16), read 2728 notes (M = 71.79, SD = 79.23), and built on 181 notes (M = 4.76, SD = 4.90). Specifically, for the building-on notes, it was found that students’ online interaction activities during their work on the problem space (i.e. before the mid-term examination) in terms of percentage, are 38% (SD = 32%). This activity amount is similar (i.e. not significant) to their activities (in terms of percentage, M = 37%, SD = 37.4%; t = 0.36, p = 0.72) during their work on the solution space (i.e. after mid-term examination). As indicated above, the pattern of online interactive KF activities was fairly consistent throughout the semester. Students’ note-reading activities (in terms of percentage) before and after the mid-term break (before: M = 9%, SD = 9%; after: M = 14%, SD = 17%; t = -1.83, p = 0.07); the insignificant pre-post change indicates that community awareness remained fairly stable.

These three quantitative indices of online KF activities are important indicators of students’ online “engagement”; however it is as important, or perhaps more important, to examine the quality of students’ collective knowledge advancement activities. To this end, we coded all ideas identified from KF notes and graded their “knowledge advancement potential” using a revised six-point version of Bloom’s taxonomy with 6 indicating the greatest knowledge advancement potential. The mean score for the whole class was 1.69 (SD = 0.60).

Group Design-Thinking Performance in a Knowledge-Building Environment

Cluster analysis was employed to measure students’ online engagement and knowledge advancement activities (using z-scores). The four clusters which emerged were named according to the online behavior they represented.

In summary, Cluster 1 (groups 1 and 6) was named “knowledge-advancing groups” because the groups exhibited high frequencies of online engagement activities and online knowledge advancement activities and thus had the best overall design performance as reflected in the sum of their scores for the four design-thinking tasks.

Cluster 2 (groups 2 and 7) was named “knowledge reproducing and sharing groups” as their online activity was dominated by online engagement activities at the expense of knowledge advancement activities and as a result, it ranked second with respect to design performance. For example, group 2 contributed a lot of information, but most was simply retrieved from online sources and not subjected to reflection and elaboration.

Cluster 3 (groups 3 and 4) was named “knowledge reflecting groups” because these groups did better than Cluster 2 at knowledge advancement activities; however, there was relatively little online engagement. This overemphasis on the former is clearly evidenced by the quality of their reflective efforts to advance knowledge. For example, group 4 worked iteratively on their initial design ideas but did not try to enrich or diversify its initial pool of ideas in order to find alternative ideas solutions (e.g. via knowledge sharing). As a result group knowledge advanced slowly and design performance was also rated as relatively poor.

Lastly, Cluster 4 (groups 5 and 8) was named "dormant knowledge groups". These groups clearly had the lowest frequencies of online engagement activities and knowledge advancement activities. For example, although the groups in Cluster 4 were able to decide their design topics they could not come up with possible solutions that might improve the design of their product. They also rarely built on each other's ideas. As a result this cluster had the worst design performance.

Overall, the findings suggest that the different clusters would need different guiding principles to further facilitate KF activities and achieve an appropriate balance between them, in order to improve design performance.

Discussion

The purpose of this study was to investigate whether working in a computer-supported collaborative knowledge-building environment, in this case, KF improves students' design-thinking capability. Students were given two knowledge-building principles to guide them through a design cycle involving four essential design-thinking tasks. To summarize, we found that engaging students in explicit, hands-on knowledge-building activities improved their implicit design thinking, in particular their divergent thinking skills. However, we also found that many students struggled with particular tasks and so it might be helpful to design some instructional scaffolds to smooth the transitions from one stage of the design cycle to another.

Moreover, cluster analysis showed that groups that demonstrated better knowledge engagement and more knowledge advancement activities also tended to have better design performance as indicated by score on the four design-thinking tasks. In other words, balanced online engagement and knowledge advancement activities in a knowledge-building environment have important effects on students' design-thinking capability. Concomitantly, we identified four types of knowledge groups: knowledge advancing groups, knowledge reproducing and sharing groups, knowledge reflecting groups and dormant knowledge groups. Knowledge-advancing groups carry out a lot of online engagement activities and high-quality knowledge advancement activity. Members of such groups are more likely to develop effective design-thinking skills than members of the other three types of knowledge groups (sharing, refining, dormant groups).

Lastly, we also found that the selection of appropriate pedagogical principles plays an important role for shaping productive learning environment. The overall finding showed that providing students with guiding principles helped create an effective knowledge-building environment in which both online engagement and knowledge advancement activities were valued. In this study two knowledge-building principles were used to increase engagement and improve the quality of advancements in knowledge. Unless attention is paid to the specific needs of each group, and guidance tailored accordingly work in a knowledge-building environment is likely to be characterized by low engagement or lack of knowledge advancement, and hence result in less effective design performance.

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