Development of Formative Assessment Tools for Knowledge Building

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Abstract

There is mounting interest in the large-scale implementation of knowledge building recently. However, there still lack of tools that are widely available for teachers and students to self-assess their knowledge building efforts. It is also critical to develop a theoretical perspective on formative assessment that is deeply integrated with knowledge building and colaborative learning. In such contexts, we propose a web-based tool for formative assessment of knowledge building which works with Knowledge Forum®. The tool adopts a three-tier system architecture and is developed by comtemporary programming languages and technologies including JAVA®, AJAX, and relational databases as MySQL®. Such system design and development cater to scalability, reusability, and future development. Extensive proofs-of-concept and testings on the tool have been performed to ensure its correctness and soundness. At the workshop, we will discuss about the underlying ideas of the tool. We will also provide sample output and engage participants in discussions about the uability of the information generated.

Introduction

In the last decade there has been much interest in education in the use of discourse — writing, reading, and other actions — in Web-based environments (e.g., Guzdial & Turns, 2000; Hiltz & Goldman, 2005). The best known environments inlcude learning management systems like Moodle® and WebCT®, and more specialized inquiry environments such as Knowledge Forum®. Knowledge building is one of the most developed educationals models that involves computer-supported discourse; one of its most important features is that students' efforts are directed at advancing the collective knowledge in a community (Scardamalia, 2002). Students are not just trying to understand things for themselves but aim to add something new to what is known in the community. In this context, Knowledge Forum is used to share and collaboratively improve and synthesize ideas.

Recently, interest in the large-scale implementation of approaches like knowledge building, which aim to help students to develop 21st century skills such as collaboration, ability to deal with novel situations, and self-regulated learning, has been mounting. However, one important challenge is that assessment tools need to become widely available that can be used by teachers and students to self-assess their knowledge building efforts. For example, to what extent can we say that there are collaborative dynamics, synthesis and rise-above, and improvement over time, and what are individual students' roles and accomplishments? Such questions access both individual and collective aspects of knowledge building, and process as well as accomplishments. Ability to have data in hand to reflect on such questions is important for the development of knowledge-building discourse.

The literature on asynchronous online discussions overwhelmingly demonstrates that such discussions have disappointing rates of participation, depth of inquiry, and knowledge advancement (Pifarre & Cobos, 2010); they often remain at the level of "conversations" in which students share opinions and ideas, and engage in superficial arguments, without

advancing the collective knowledge of the community. Although we have made progress in conceptualizing the nature of discourse required (Scardamalia & Bereiter, 2006; Author, 2006, 2009), better assessment tools are needed. Currently assessments of online discourse consist of content analyses that examine specific features of the discourse (e.g., how knowledge is constructed, the epistemic levels of students' questions and ideas, and how ideas are diffused), but these types of analysis are too labor-intensive to inform students' efforts while they are in progress. To scale up approaches like knowledge building, it is essential to develop assessment technologies that can provide students and teachers with useful information about their discourse and what it is accomplishing — and that such tools can be used by teachers and students' themselves. For the knowledge-building community the problem is urgent because the Analytic Toolkit for Knowledge Forum is becoming technically outdated, and does not provide all of the analyses that are now needed.

Our research program on formative assessment of knowledge building focuses on the use of data stored on the Knowledge Forum server to provide students and teachers with information about the quality and extent of their knowledge building, and the study of how they use such information improve their knowledge building. An important aspect of this work is the development of tools that visualize the semantic features of Knowledge Forum databases. Important progress in this direction has been made by Author *et al*., who developed the Knowledge Space Visualizer (Author, 2010;Author *et al.*, 2007). Here, however, we focus on a simpler approach, in which server log data such as those retrieved by the Analytic Toolkit (Burtis, 1998) form the basis of the assessments. Our collaboration with many teachers in the Knowledge building Teacher Network (KBTN, kbtn.cite.hku.hk) indicates that simple representations of the data are needed if teachers are to use them – particularly where teachers are concerned who avoid mathematics. Our goal is to develop indicators of knowledge building that are intuitively linked to the most important aspects of

knowledge building, including cognitive responsibility for collective knowledge and idea improvement. We believe that it is especially important to create assessments that can be used to reflect on collective aspects of knowledge building, to counteract tendencies of teachers and students to focus on individual accomplishments and efforts. There also are technical challenges with the further development of the Analytic Toolkit that have to do with the commensurability and interoperability of Knowledge Forum and ATK codes. Our approach is to convert the Knowledge Forum tuplestore data to relational database format, and use the resulted database as the basis for the development of our assessment environment. MySQL has the advantage that it is open source and widely used, so that the assessment concepts that we are developing can in principle be applied to other interactive systems that use MySQL databases, such as Moodle®.

This paper reviews relevant literature, and then describes the overall architecture of our assessment system. Following this, we discuss concepts that guide our development of assessments that can be used by teachers and students to improve their knowledge building. The paper provides the background to a workshop at which we explore the potential of the kinds of assessments that we are designing. In other words, at the Summer Institute we will generate assessment data from several Knowledge Forum databases, and discuss their potential uses with participants.

Formative Assessment

In various forms, assessment drives educational practice (Biggs, 1996). It is therefore important for innovative educational approaches from the learning sciences to demonstrate that quality outcomes are obtained, but also how the processes involved in the approach contribute to them, and how the relationships among them can be enhanced. For example, if work in Knowledge Forum supports collective knowledge advancement, how do we know if

the discourse in Knowledge Forum is likely to produce this effect? How does collective knowledge form and develop while students collaboratively learn online?

We use the concept of *formative assessment* (Scriven, 1967) to frame our work: assessment used by students and the teacher to reflect on knowledge building, when it is still in progress, and that is used to enhance knowledge building. Interest in formative assessment received a boost after the major review by Black and Wiliam (1998), which showed substantial positive impacts of formative assessment on learning. However, these practices seem to focus on such things as providing feedback on student work (e.g., tests and projects) and in-class questioning.

Several authors have called for further theoretical development of the concept of formative assessment. For example, Taras (2005, 2009) suggested that the dichotomy between formative and summative assessment in the literature was not intended by Scriven, and called for better integration of the two concepts. She explained that the concept of formative feedback proposed by Ramaprasad (1983) involves information about the gap between actual performance and a reference level (a standard), and therefore has a summative aspect. Assessment, whether its function is formative or summative, involves a judgment about quality relative to some criterion. Yorke (2003) acknowledged the positive results of formative assessment, but questioned their educational implications. For example, if the final product that students create is enhanced by feedback from the teacher at a draft stage, will they be able to perform adequately when such feedback is not available, or does formative assessment produce "learned helplessness"? He also suggested that the merit of the final product could be a function of the effort that the teacher invested in providing feedback on a draft, rather than just the student's own effort and ability. However, if collaboration becomes the dominant mode of learning in society, these issues seem less important. Finally, Perrenoud (1998) pointed out that Black and Wiliam had missed an important literature

published in French, which developed *regulation of learning* as a central concept integrating formative assessment, the didactic content of the disciplines, and differentiation in teaching. This view of formative assessment is based on a stronger theoretical foundation of cognitive theory of learning that involves scaffolding. However, Perrenoud's concern was mainly with regulation by the *teacher*, not by students.

One aspect of our work is to develop a theoretical perspective on formative assessment that is more consistent with knowledge building, and a general review of assessment in collaborative learning that includes formative assessment is given by Author (submitted). Here we only point out that for knowledge building a view of formative assessment is needed that deeply integrates assessment with knowledge building. We consider assessment as the collection of information involved in students' own inquiry into their knowledge building. It is not epistemologically distinct from knowledge building, except that the domain of the inquiry is not subject matter (e.g., science concepts) but the process of knowledge building. In other words, as Scardamalia (2002) puts it, assessment is "embedded" in knowledge building and "transforms" it. A theoretical understanding of formative assessment involves attention to the regulation of learning, but whereas Perrenoud (1998) focuses on regulation by the teacher and self-regulated learning on regulation by the self (Winne & Hadwin, 1998), knowledge building seems to require a more social view of regulation. Here, we do not dwell on such matters and focusing more on the tools that are designed to support formative assessment by providing students and their teacher with evidence of their knowledge building efforts.

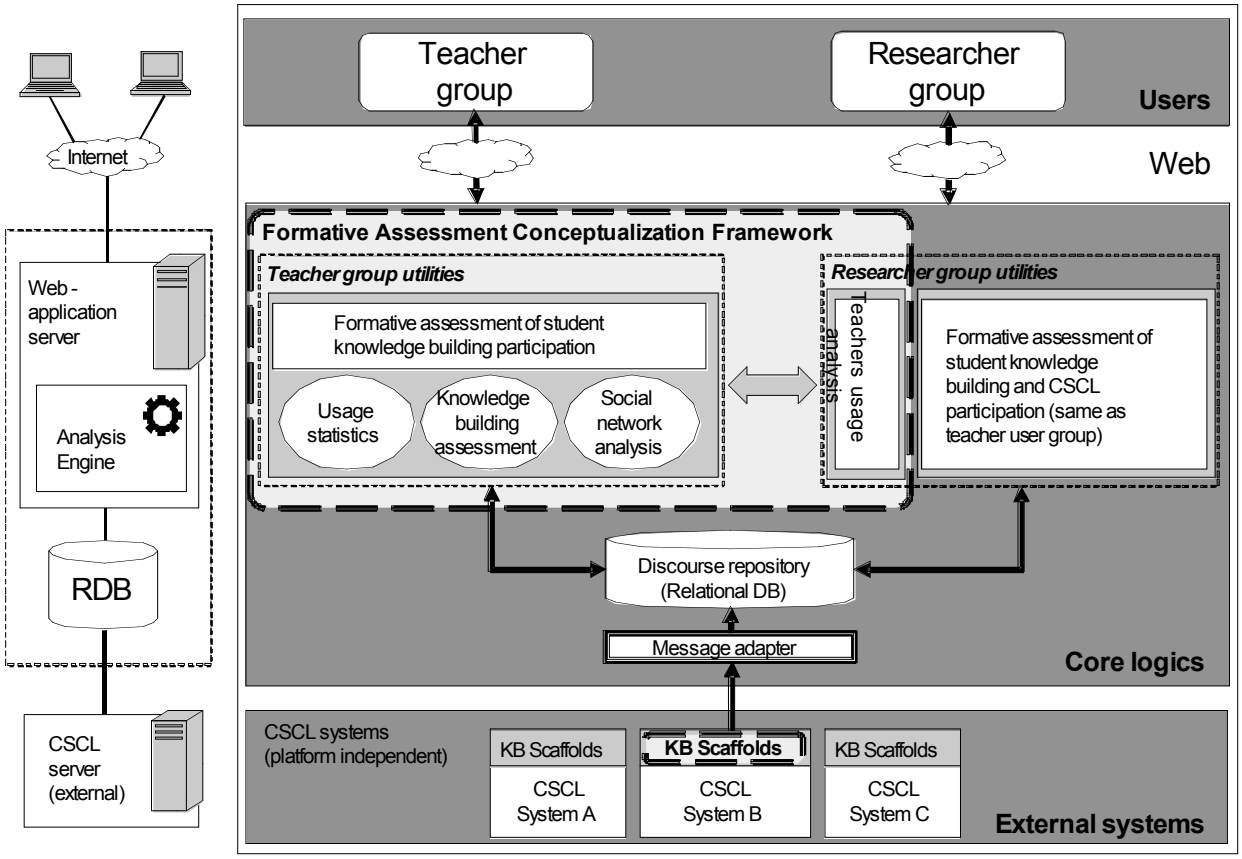
Design

Purposes of System and Key Features

We are developing a web-based system for teacher-driven and student-driven formative assessment. It is implemented using current development technologies (such as SQL data structure, rich internet clients (AJAX), and multi-tier system architecture), which enhance the *sustainability* and *efficiency* of existing proprietary CSCL systems analysis tools. A special feature is that while many CSCL analyses tools are designed for researchers, this system is designed teachers and students. While we will work with Knowledge Forum databases, the system will be designed to be platform independent.

System Architecture

The overall architecture of the system is shown in the figure. The functional architecture is shown on the right, and the corresponding technical architecture on the left. The architecture consists of three layers: (1) user, (2) core logics, and (3) external system.



- The ***user layer*** provides user-related utilities such as the web-based user interface, user profile management, and user authentications. In particular, all web communication will be encrypted with the Transport Layer Security (TLS) mechanism.
- The ***core logics layer*** hosts the core function logics that implements the formative assessment conceptualization framework.
- The ***external systems layer*** is where the generic CSCL systems reside (e.g., Knowledge Forum). These CSCL systems are external in a sense that they can be any architecture for CSCL discourse transactions.

Real time communication between the core logic layer and the external CSCL systems is not necessary. Such design maintains the platform and system independencies of the external systems layer. In order to further support a wider-range of proprietary data format resides in non RDBMS-based discourse repository (e.g. the Knowledge Forum™ tuplestore), a message adapter will also be implemented in the current project to convert the proprietary data format into that interoperable by general relational databases and SQL query logic).

Concepts Influencing Design of Assessments

We will use a natural language approach for developing assessments. The basic idea is that students would be able to ask basic questions about their knowledge building, and that they would get answers that provide a level of detail and complexity that they can manage. The questions should focus on what is most important about knowledge-building discourse. This approach will be student-oriented rather than analysis or data-driven, as the ATK is. That is, it should focus on the kinds of questions that students should have about their discourse. Below we outline indicators for several basic questions. These ideas should be discussed further. Then we should make some mock-ups to get specific ideas and test the mock-ups with teachers before going into the programming.

Are Wwe Collaborating?

With "collaboration" we refer to any activity by means of which people work together to accomplish a shared goal. The discourse in knowledge-building environments is collaborative in that the ideas and contributions of individuals combine to produce collective knowledge advances. A community working together can accomplish more than any one participant can alone. When there is an ethos that makes collaboration possible, there is likely to be greater idea diversity and democratization of knowledge. However, collaboration is pragmatic – participants to collaborate to accomplish a goal. Thus, for example, after an idea has been examined from a variety of perspectives (e.g., what the writer intended to say, testing the idea, helping to make its significance clear), students may no longer feel it is necessary to comment or raise questions about it. At such a point, synthesis across ideas rather then work on a specific idea may be more useful. In other words, collaborative actions need to be understood in socio-historical context. It would make little sense to assess if individual students are contributing ideas – e.g., "everyone must contribute one idea per week" – but clearly as a whole the community must generate many ideas.

With the set of analyses that fall under "Are we collaborating?" we are interested in knowing whether we can say about the community that collaboration is occurring – we consider collaboration a dynamic or property of the community, even though it is impossible for a community to have this dynamic if students are not individually engaging in it. The main reason we take this stance is the competitiveness of educational environments. In many Hong Kong classrooms students are still ranked within their class, which leads to a tendency by teachers to collect assessment data at the individual learner level. Competiveness can be quite counter productive to knowledge building. We have found that some students do not want to contribute their ideas to Knowledge Forum for fear that others will "steal" them (Author *et al*., 2006). In addition, information about the community as a whole is simpler to

digest than detailed information about individuals that must be aggregated. If collaboration is to be a community goal, then participants need information at that level for setting and reviewing their community goal.

Collaboration is premised on a set of social relations (Kirschner & Kreijns, 2005; Author, 2009; Wegeriff & Scrimshaw, 1994). For example, before people are likely to collaborate there must be a high level of trust and confidence in the process. If participants think that others will take credit for their ideas it becomes difficult to collaborate; if participants are blatantly unaware of the ideas that have been contributed it becomes difficult to believe that the collaborative process will lead to knowledge advancement for the community. Here, we consider the structural features of a community in which collaboration is occurring and assume that most participants should have some "collaborative friends" – participants who interact with their contributions. Collaborative friends may read each other notes, build onto some notes, or use friends' ideas in their own work in productive ways (e.g., provide examples, raise questions about, link to other ideas, but do not present as one's own). We see "friendship" as defined by such interactions. Thus, we are not saying that participants should follow and use only the contributions of their everyday friends (students to who they feel bonds and with whom they share out-of-class interests). Participants should be inclined to follow the work of others because they generally believe that it has merit, and use it if they think it will benefit their own pursuits in the community. If there are many participants who have no collaborative friends, then their efforts are not making a contribution to the community – they are not read, built-on, or utilized. In that case we would not have democratization of knowledge.

In terms of natural language, the assessments we are developing provide answers to questions such as the following:

- What percentage of participants can say they have at least 7 collaborative friends who read their notes?
- What percentage of participants can say they have at least 4 collaborative friends who build on their notes?
- What percentage of participants can say they have at least 2 collaborative friends who read some of their notes more than once?
- What percentage of participants can say they have at least 2 collaborative friends who use their ideas (e.g., use notes as references, use keywords that they first introduced)?

The thresholds for being a friend can be set by the person doing the analysis. For example, one could define a friend to participant P as a participant who reads at least 3 notes by P in a two-week period.

Are We Putting our Knowledge Together?

Among the most important features of discourse lacking in many Knowledge Forum databases are synthesis and rise-above (Scardamalia & Bereiter, 2006). Indeed, considerable experience collaborating with teachers suggests that the dominant form of discourse is knowledge sharing, which involves the exchange of ideas and information; knowledge construction, the inter-subjective meaning making by which students come to understand ideas, is less common; and the discourse in which ideas are synthesized and become part of the community's work (i.e., their used is diffused), is still rarer (Author, 2009). Thus, assessments are needed that can reveal the extent to which synthesis and rise-above are occurring. The teacher and students need to interpret results from such assessments in terms of their goals and understanding of knowledge building. We are currently considering the following indicators:

- *Number of notes in the database that are opened more than once by a same reader:* Synthesis minimally involves re-reading notes that have been read before, to see possible connections and patterns. Looking at the number of notes that have been reopened gives a first indication whether participants are returning to notes at all. (Hewitt, 2005) suggests it does not occur much. If it does occur, we can also identify *sessions* during which participants are reviewing the database. For example, if we find that a student opens 10 notes again within a few minutes and keeps them opened, this may signal a review session.
- *Number of notes in the database that include references (links) to other notes:* This goes a step further than simply rereading notes, and involves making connections between them. This can be done a number of ways in Knowledge Forum, for example, by quoting from one note in another note. The rise-above note is another example.

As in the previous section, we are most interested in these kinds of indicators at the community level. Not everyone needs to be involved in this kind of work frequently, but in a knowledge-building community there must be evidence that it is occurring. Over *long* periods of time, we can ask more questions at an individual level. Perhaps it is reasonable to expect that after 5 months on Knowledge Forum the majority of students have created references between notes at least a few times. Again, the percentage of students of who this is the case would provide a community indicator of linking, showing that linking notes takes place.

What Happens to Ideas over Time?

That ideas are improvable is another key principle of knowledge building (Bereiter, 2002; Scardamalia, 2002). One indicator of this is that the community's ideas are improved over time, a question that requires semantic analysis. But other important questions have to do with the diffusion of ideas and sustained work on them. For example, after a student

introduces a new concept, do others begin to use it, or does it remain an unrecognized event? We are exploring the following indicators:

- *Awareness of new concepts:* After a keyword is introduced into the database, how does awareness of it grow over time? For example, if 10 students read the note in which a keyword is first introduced, but 10 other students encountered the keyword in later notes, then 20 students have seen the keyword used in at least one context. If no notes other than the original one used the keyword, only 10 students are aware of it from the database – and the awareness is based on a single example.
- *Use of new concepts:* Complementary to this idea is focus on the *use* of new concepts. This can be traced by examining the uses of keywords in new notes, on the assumption that a keyword signifies a concept (i.e., that keywords are pedagogically used that way). We can examine whether the use of a keyword is sustained over time and whether it diffuses through the community. Instead of signifying concepts, keywords may also be used to examine a list of epistemic words, such as theory, evidence, and explain (Sun, Zhang, & Scardamalia, 2010).

There are further possibilities along these lines. For example, by correlating the above keyword patterns with the introduction of new information and scaffolds supports such as 'I need to understand', 'My theory', and 'A better theory', we can examine the extent to which new information is processed. This is important for assessing the principle of constructive use of authoritative sources. Some studies suggest that information, if it is introduced at all, is frequently treated as unproblematic, and leads to little question-asking and theorizing effort (Author, 2009).

Another dynamic of knowledge building is that the types of contributions should change over time. For example, very early in the history of a topic, participants should be contributing ideas and questions, and comment on these to help to develop them. Perhaps a

little later, we might see more effort to introduce new ideas from authoritative sources (Web pages, books, television programs, but also experiments, field trips, etc.). Still later, we may see evidence that participants are reviewing progress and synthesizing ideas. As a knowledge-building community develops over long period of time – e.g., Grade 4 compared with Grade 3 – we also would expect to see changes in the dynamics. For example, participants may spend relatively more emphasis on synthesis and rise-above, and may star to do so earlier in an inquiry.

In sum, the assessments we are developing in this area focus on traces of idea improvement provided by correlating keyword use and awareness with other indicators. This is important for examining that ideas are improving and are diffused. However, it is equally important to be able to assess the long-term development of knowledge-building practices independent of the topics that are being investigated. This is the case because knowledge building is considered an epistemological theory (Scardamalia & Bereiter, 2006), so participants should grow in epistemological understanding – e.g., understand the epistemological nature and roles of information and information, and the dialog between theory development and reviewing progress. It seems important to have evidence that participants are learning *how* to build knowledge, so that it becomes an approach that can pervade how participants deal with knowledge gaps.

What's happening to My Stuff?

Despite emphasis on community and collective aspects of knowledge building, it is also important for participants to be able to reflect on *individual* contributions and accomplishments. All members of a scientific discipline share the goal of advancing that discipline, but accomplishments are primarily at the level of individual accomplishments – or those by a specific lab. Similarly, in school it is important to recognize the accomplishments of individuals. Although we are not focusing here on summative assessment that could be

used to support high-stakes decisions (e.g., report cards, promotion to the next grade), we aim to put tools in the hands of students that they can use to gather how they, personally, are doing. Our system will have a personal page which required user logon, such that only authenticated and authorized individual participants can assess to its contents. The assessments we are considering here are similar to those in the earlier assessments, but are presented at the individual level. Thus, earlier we focused on the percentage of participants who had at least a certain number of collaborative friends, but now we focus on who those friends are.

We are focusing on three types of indicators:

- *My friends*: Similar to social networking environments like Facebook®, this tool reveals the immediate world of a participant in the community. A participant will be able to select a type of friend (e.g., reading, building-on, referencing) and criteria (e.g., 5 instances in 2 weeks). A list of pictures of the retrieved collaborative friends will then be displayed. The benefit of this tool is that it reveals participants in the database who see to have similar interests. In some cases they may already be collaborating, but in other cases, it may suggest possible new collaborations.
- *My most influential notes/ideas*: The goal of this tool is to help participants gain an understanding of the kinds of contributions to Knowledge Forum that make a difference. For example, if participants return to some notes frequently, is it for the information presented, a new idea, synthesis, or perhaps all three? Indicators that we are considering include:
    - Which notes created by me were read more than once?
    - Which notes created by me were read by more than *n* students?
    - Which notes created by me have been used as references?

- Which notes created by me have been incorporated into rise-above notes or notes that include more than m references?

- *What's happening to my most prized ideas?* This is a variation on the previous tool. Here participants select notes that they feel have significant ideas or initiatives, and monitor the uptake of the notes in the community through reading, reading more than once, build-on, referencing, and incorporation into rise-above notes. This tool can be used in conjunction with the previous one. Based on reflection on his/her previous contributions and perhaps discussion with others, a participant may make a special effort and contribute some notes that use a new strategy (e.g., not only providing a Web link to information, but evaluating it in the context of the ongoing discussion); this tool can then be used to track whether this strategy is effective. Instead of notes, it is also possible to focus on keywords/concepts.

These tools can be used in the context of the knowledge-building portfolios (Author *et al*., 2007). Early in our work on portfolios we asked students to consider evidence of the knowledge-building principles among their own notes. Later, we relaxed that requirement because in knowledge building efforts of short duration, participants may not have created notes that demonstrate the principles. However, when the group becomes more mature in its knowledge building, and we consider knowledge building over many months, this becomes less important.

Progress and Workshop

Our assessment system is based on a relational database (MySQL) version of the Knowledge Forum tuplestore database. Specifically, we have recreated the following analyses indicators from the ATK: notes created, percentage of notes with links, percentage of notes with keywords, notes read, distinct notes read, note revisions, scaffold uses, and

relational data including who's read whose notes, who's built onto whose notes, who's referenced whose notes. We have done extensive testing to compare ATK results with those of our MySQL version. This testing was necessary to ensure that we are thinking correctly about the data that we take from the tuplestore. Of course, there are no mathematical errors, but it is possible that we interpret the data incorrectly, and thus have obtained a different measure than we intended. At writing, only a small number of minor issues remain, leading to an overall error rate of 5%. Testing is continuing, and we expect to do even better at the time of the Summer Institute. The MySQL database is the foundation for our assessments, which are written as SQL (Structured Query Language) queries. Using MySQL as our database solution has the advantage that it is open source and used widely, so that we are developing expertise to develop the assessment tools for other systems that uses MySQL or other relational databases. We are now developing the assessment tools, and expect to have the majority of features discussed above operational at the Summer Institute.

At the workshop, we will discuss the underlying ideas informing the assessment tools and consider their use in formative assessment of knowledge building. Specifically, we will provide sample output from analyses, and engage participants in discussions about the usability of the information generated.

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