Proceedings of the Workshop on Computer-Based Learning Environments for Deep Learning in Inquiry and Problem-Solving Contexts

The Pre-Conference Workshop at the12th International Conference of the Learning Sciences

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21 June 2016
Singapore

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Preface

Theoretical background

Knowledge is assumed to be better constructed through interaction with problem-oriented, socially situated environments, as claimed in situated cognition theory (Brown, Collins, & Duguid, 1989) and situated learning theory (Lave & Wenger, 1991). The two theories share a common view that situation and cognition are interdependent; cognition is a process occurring in physical and social contexts where knowledge is created and applied. Accordingly, learning in real-world situations, especially with ill-structured problems (Jonassen, 1997) and authentic, whole-task experience (Van Merriënboer & Kirschner, 2013) has become the central aspect of educational practice.

Given the constraints of classroom settings in offering learning with real-world problems and authentic tasks, computer-based environments have been increasingly explored to support situated learning in virtual environments. In spite of technology support, effective learning through problem-solving and authentic task experience is difficult to realize because learning in such contexts involves complex processes in multiple aspects (Wang, Wu, Kinshuk, Chen, & Spector, 2013). Such complexity may overburden learners, but is often underestimated by instructors or experts for whom many of the requisite processes have become largely subconscious because of years of experience (Reif, 2008). As a result, many learners are not adequately empowered to achieve the potential of situated learning.

It has been noted that open-ended exploration in inquiry and problem-solving tasks generates heavy cognitive load to learners (Kirschner, Sweller, & Clark, 2006), and the use of scaffolding is important to learning in such situations (Hmelo-Silver, Duncan, & Chinn, 2007). This is aligned with the cognitive apprenticeship model, which claims that carrying out a complex task usually involves implicit processes; it is critical to make such processes visible for novices to observe, enact, and practice with expert help (Collins, Brown, & Holum, 1990). Although theoretical principles offer the foundation for understanding learning in authentic situations, the design of computer-based environments and integrating them in situated learning are often associated with sophisticated and ambitious educational reform for which the implementation process is uncertain or ill-specified. While learning with real-world problems and authentic tasks is increasingly being used in educational practice, there is a concern about its weakness in instructional design and mixed learning outcomes. The mixed learning outcomes are also related to the use of examination-oriented assessment methods, which are not sensitive to learning in authentic contexts (Gijbels, Dochy, Van den Bossche, & Segers, 2005).

This workshop attempts to explore how the potential of whole-task and problem-oriented learning can be better realized through effective design and implementation of computer-based learning environments, and appropriate analysis of learning in such environments. The participants are expected to present their studies relevant to this theme in a variety of settings such as science education, professional development, and medical education, among other. In addition to sharing specific approaches and findings, we encourage open discussions on various challenges experienced in conducting such design-based research (e.g., methodological complexity, extended research process, need for domain knowledge, and commitment to advancing both theory and practice), as well as strategies to deal with the challenges.

Learning through executing real-world learning tasks is not new. It is more important than ever in today’s rapidly changing world, where learners are required to deal with more sophisticated real-world problems, and have more exposure to authentic experience. The output of this workshop will advance research and practice on how situated learning in technology-mediated environments can be adequately empowered to achieve desired outcomes.

Workshop goals

This workshop is intended to draw scholars who are interested in design and implementation of computer-based learning environments that foster deep learning with real-world problems and authentic tasks, and analysis of the learning in such environments. The workshop will provide a platform for the scholars to share their studies and findings, challenges experienced in conducting such design-based research (e.g., methodological complexity, extended research process, need for domain knowledge, and commitment to advancing both theory and practice), as well as strategies to deal with the challenges.

Workshop organizers

Minhong (Maggie) Wang is an Associate professor with the Faculty of Education at the University of Hong Kong. Her research has focused on thoughtful design, implementation, and assessment of educational technology in the contexts of workplace learning, higher education, and secondary education. Her research aims to provide learners with necessary support to achieve high levels of autonomy, confidence, and performance when they work with challenging problems, such as managing complexities involved in problem-solving and knowledge-construction processes in problem-oriented learning contexts, and dealing with cognitive overload and disorientation experienced in interaction with a large amount of online resources. Her research has featured a theory-driven design of technologies for learning and instruction as well as the necessity for continuous development and practice for enriching design principles for technology-enhanced learning.

Paul A. Kirschner has recently been appointed as Distinguished University Professor at the Open University of the Netherlands. Before that he was Full Professor of Learning and Cognition on the Welten Institute Research Centre for Learning, Teaching and Technology, Open University Nederland. He is an internationally recognized expert. His areas of expertise include lifelong learning, computer supported collaborative learning, designing electronic and other innovative learning environments, open educational resources, media-use in education, development of teacher extensive (distance) learning materials, use of practicals for the acquisition of cognitive skills and competencies, design and development of electronic learning and working environments, and innovation and the use of information technology educational systems.

Susan M. Bridges is an Associate Professor with the Centre for the Enhancement of Teaching and Learning and Assistant Dean (Curriculum Innovation) with the Faculty of Education at the University of Hong Kong. Her work focuses on curriculum and staff development, including e-learning initiatives, to enhance student learning outcomes. She led a 2012 HKU Outstanding Teaching Award (Team) for work on blended learning in Dentistry. Her research interests are interactional and ethnographic, exploring the ‘how’ of effective pedagogy. Recent publications include a co-authored chapter on problem-based learning in the Cambridge Handbook of Learning Sciences, 2nd Edition. She currently chairs a Working Group reforming initial teacher education curricula using inquiry-based designs. She also runs workshops in higher education on blended approaches to PBL curriculum design. Her 2015 co-edited book Educational Technologies in Medical and Health Sciences Education published by Springer examines the role of technologies in situated learning – both inquiry-based and clinical contexts.

Acknowledgements

The workshop organizers would like to thank Sharon J. Derry for her kind help on running and coordinating the workshop. Thanks also go to Susanne P. Lajoie and Cindy E. Hmelo-Silver for their warm support for making the workshop a success.

References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*, 32–42.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator, 15*(3), 6–46.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, *75*(1), 27–61.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99–107.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*, 65–94.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Reif, F (2008). *Applying cognitive science to education: Thinking and learning in scientific and other complex domains*. Cambridge, Mass.: MIT Press.

Van Merriënboer, J. J. G., & Kirschner, P. A. (2013). *Ten steps to complex learning* (2nd ed.). New York: Taylor & Francis.

Wang, M., Wu, B., Kinshuk, Chen, N. S., & Spector, J. M. (2013). Connecting problem-solving and knowledge-construction processes in a visualization-based learning environment. *Computers & Education, 68*, 293–306.

Toward an assessment algorithm for evaluating online collaboration to promote deep and useful understanding of conceptual material

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Abstract: I have taught and conducted research in online learning for a number of years. I currently teach an online class (Human Abilities in Learning, aka HAL Online) in which undergraduates study conceptual material about the science of learning, then deepen their understanding of the material by using it in small-group collaborative problem solving that takes place asynchronously online. Important components of the HAL Online design include: 1. Repeatedly requiring students to use course concepts as input to authentic collaborative problem solving activities designed to strengthen understanding and use those concepts. 2. Presentation of problem-solving tasks using cases, including video cases, leading to repeated and varied application of course material in realistic conditions. 3. Fostering and reinforcing effective collaborative *processes* through *training and assessment* that requires thoughtful and timely online participation as well as argument with evidence. The HAL Online formula accords well with current knowledge and theory about fostering deeper learning and provides a reasonable scalable model for online college instruction that is likely generalizable to other domains. The author and other instructors have taught HAL Online or very similar courses across many semesters and, in recent years after design stabilization, have been rewarded with positive student evaluations. Further, research results reported below demonstrate the effectiveness of the approach measured in terms of non-trivial assessments of deeper learning. However, this instructional method, which involves continuous online assessment of collaborative process, is time consuming and resource intensive, making scaling up a challenge within institutional environments that have limited instructional resources. A strategy discussed in our workshop presentation would develop plugins compatible with widely used course management systems that could support instructors of large HAL-type courses by providing improved analytics and automated forms of assessment.

Keywords: Assessment algorithm; Evaluating online collaboration; Deep and useful understanding; Conceptual material

1. Research results

Colleagues and I have developed innovative online environments for experienced-based learning that have served as contexts for research on activity design and development of students' conceptual knowledge and critical thinking. Studies of these designed environments have consistently demonstrated impact with moderate to large effects on student learning, thinking, and collaboration in pre-postest designs (Derry & Hmelo-

Silver, 2005), comparisons with intact classrooms (Derry et al., 2006; Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009), matched comparisons (Derry, Gressick, & Hackbarth, 2014; Eagan, 2010), contrasting case studies (Gressick & Derry, 2010), and randomized controlled studies (Beitzel & Derry, 2009; Gressick & Derry, 2013a; 2014).

In one study of HAL Online specifically (Eagan, 2010), students performed substantially better than matched students from comparison courses on an assessment that required using learning-science concepts to: 1. Analyze children's mathematical reasoning observed in naturalistic video; and 2. Make pedagogically appropriate responses. Results were equally strong for college learners with varied levels of expertise and comfort with mathematics. In this study, both HAL Online and comparison courses were taught by highly rated instructors and endeavored to address similar conceptual content. A second study, a controlled experiment (Gressick & Derry, 2013b; 2014), demonstrated positive effects of early argument training on individual student learning and on group meaning-making in the HAL Online environment. For a very complex collaborative analysis activity that required integration of text and video, students who experienced argument training early in the course correctly incorporated into their discussions more scientific material, and they conducted more exacting and careful search of video cases to identify evidence related to the theory. Effects on student resource use lasted many weeks after the argument training treatment, indicating that direct training in argumentation prepared students for future learning (Bransford & Schwartz, 1999).

2. Challenges

The small-group collaboration process is an important engine that drives learning. Thus in HAL Online implementations, students' online behaviors and conceptual contributions to their group's problem solving are constantly monitored and evaluated, not only to alert the instructor to groups that require online support, but also to assign individual grades for online contributions, which strongly influence student engagement. For each problem solving activity, each student receives a grade reflecting an assessment of their involvement in the problem solving in ways that document their understanding of and ability to use learning science concepts. To assess the quality of online participation, I study and rate students' participation using a rubric such as the following:

HAL Online Rubric for Evaluating Students' Forum Work

Throughout the course you are required to engage in a forum discussions with other class members. You will be evaluated on your forum contributions twice during the semester, once at midterm and once at the end of the course. Your average forum grade will count 25% of your final course grade. The following criteria will be used in evaluating your forum contributions.

1. *Do you make a sufficient number of contributions? There is no set limit or number required, but a good rule of thumb is at least 4 thoughtful posts per forum (not per discussion topic).*
2. *Are your discussions thoughtful, intelligent, and mature (rather than just expressing personal opinion)? Do you hold yourself and others accountable for good evidential thinking?*
3. *Do your posts specifically connect the forum discussion topics to the readings, providing evidence that you have studied the material and are thoughtfully connecting ideas from the course to the forum issues?*

4. *Do you participate in a discourse (versus post at the last minute)? Forum discussions usually start on a day a little before the week's topic closes and they wrap up before the beginning of the next topic. Engaging in the forum discourse throughout the period rather than just throwing up a few posts on the last day will improve your grade.*
5. *Have you been a good group citizen, taken on some leadership -- starting discussions, serving as chair or summarizer, helping keep the group on task, fostering a spirit of critical inquiry, contributing positive energy to the group?*

However, using this rubric, one instructor cannot manage a very large course because evaluating collaborative work online is very resource intensive. This instructional method could be implemented on a much larger scale if only there were a way to automate the process of evaluating group collaboration around problem solving challenges.

3. Strategies

A proposed "plugin" dashboard for widely used course management systems would provide analytics to support instructors in rapidly evaluating small-group collaboration for large courses designed like HAL Online. Current analytics capabilities in available course management systems provide support for evaluating student performance in terms of items 1, 4, and, to some extent, 5 in the rubric above. However, further technical developments are required to support large-scale student evaluation on items 2 and 3.

Because the collaborative problem solving tasks used in HAL Online and similar courses must be thoughtfully developed and evaluated over multiple iterations, each such task becomes associated with a range of high-quality student solutions and a reasonably settled set of course concepts that can be employed in reaching these solutions. Thus, an algorithm based on latent semantic analysis or a "bag of words" approach could assist an instructor supervising many online groups in evaluating whether groups were using task-appropriate conceptual material from a course. A more sophisticated algorithm based on studies of high-quality collaborations and informed by previous work on coding systems for online collaborative argument (e.g., Clark, Sampson, Weinberger, & Erskens, 2007; Weinberger & Fischer, 2006) would in addition: 1. Attend to conversational markers in order to evaluate the structure of collaborative arguments and 2. Determine whether course concepts were used in positions as evidence in these arguments. However, to assess and support individual student performance in collaborative contexts, which we argue is necessary, the algorithm would also need to estimate the extent to which specific individual students were contributing course concepts in critical positions within evidential argument. The challenge of identifying and assessing individual contributions to online conversation is one way that automated assessment of student performance within a collaborative course context differs from automated assessment in an individualized course context.

My research group is coding online discussions from HAL Online with the goal of providing the underlying structure for such an algorithm. Our goal is to share this work in progress with other scholars in hopes of collaborating with researchers who have technical expertise to help design a dashboard-based assessment system for online collaborative process that could be used as a plug-in by users of Sakai, Moodle, or other course management system.

4. Conclusions

We know how to design effective online courses that foster deep learning through online asynchronous collaboration that is guided and closely assessed. However, evaluating collaborative work online and in real time is very resource intensive, making large-scale implementation of effective collaborative methods problematic. Online collaborative learning could be implemented on a much larger scale if there were plugins, available in IMS format, for common course management systems, that could at least partially automate the resource-intensive process of evaluating group collaboration around carefully design problem solving challenges that require use of specific course content. Our work in progress that will be shared in this workshop is building a foundation for furthering this agenda.

References

Beitzel, B. D., & Derry, S. J. (2009). When the book is better than the movie: How contrasting video cases influence text learning. *Journal of Educational Computing Research, 40,* 337–355.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. Review of Research in Education, 24, 61–101.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review, 19*, 343–374

Derry, S. J., Gressick, J. & Hackbarth, A. J. (2014, April). *Design research with VMC-based instructional activities for online teacher education*. Paper presented at AERA Annual Meeting as part of symposium, The Video Mosaic Collaborative: An Online Professional Development Resource for Mathematics Education and The Learning Sciences (S. J. Derry Organizer/Chair).

Derry, S. J., & Hmelo-Silver, C. E. (2005). Reconceptualizing teacher education: Supporting case-based instructional problem solving on the World Wide Web. In L. M. PytlikZillig, M. Bodvarsson, & R. Bruning (Eds.), *Technology-based education: Bringing researchers and practitioners together* (pp. 21–38). Greenwich, CT: Information Age Publishing.

Derry, S. J., Hmelo-Silver, C. E., Nagarajan, A., Chernobilsky, E., & Beitzel, B. (2006). Cognitive transfer revisited: Can we exploit new media to solve old problems on a large scale. *Journal of Educational Computing Research, 35*, 145–162.

Eagan, B. A. (2010). *Video assessment of reasoning about children's mathematical reasoning.* Unpublished Masters' Thesis, Department of Educational Psychology, University of Wisconsin-Madison.

Gressick, J., & Derry, S. J. (2010). Distributed leadership in online groups. *International Journal of Computer Supported Collaborative Learning, 5*, 211–236.

Gressick, J., & Derry, S. J. (2013a). The influence of training in argumentation on students' individual learning outcomes. In N. Rummel, M. Kapur, M. Nathan, & S. Puntambekar (Eds.), *To See the World and a Grain of Sand: Learning across Levels of Space, Time, and Scale: CSCL 2013 Conference Proceedings* (Vol. 2, pp. 38–41). International Society of the Learning Sciences.

Gressick, J., & Derry, S. J. (2013b). *Adventures in argument: How training in argumentation influences domain learning and scientific literacy*. Paper presented at AERA Annual Meeting, San Francisco, CA.

Gressick, J., & Derry, S. J. (2014). Adventures in argument: Training in argumentation influences student resource use in collaborative meaning making. In J. L. Polman, E.

A. Kyza, D. K. O'Neill, I. Tabak, W. R. Penuel, A. S. Jurow, K. O'Connor, T. Lee, & L. D'Amico (Eds.), *Learning and becoming in practice: The International Conference of the Learning Sciences (ICLS)* (Vol. 1, pp. 370–377). Boulder, CO: International Society of the Learning Sciences.

Hmelo-Silver, C. E., Derry, S. J., Bitterman, A., & Hatrak, N. (2009). Targeting transfer in a STELLAR PBL course for pre-service teachers. *International Journal of Problem-Based Learning, 3,* 24–42.

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education, 46*, 71–95.

Instructional dashboards to support deep learning in an online problem-based learning environment

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Abstract: Technology-rich learning environments provide opportunities to enhance and support collaborative learning. One such instructional approach to collaborative learning is problem-based learning (PBL). Moving PBL online provides opportunities to extend skilled facilitation resources to larger numbers of groups and to move beyond the limitations of synchronous learning. We have designed and developed a dashboard to support instructional decision-making in online learning contexts. In this paper, we discuss the challenges, design and findings based on the latest phase of our study analyzing the use of visualizations to support instructors.

Keywords: Problem-based learning; Collaborative learning; Learning analytics; Medical education

1. Introduction

Problem-based Learning (PBL) is a pedagogical approach in which students begin their learning with an ill-structured problem. In small groups, students iteratively cycle though a tutor-facilitated process that includes problem definition, identification of relevant facts, hypothesis generation, identifying gaps in knowledge, self-directed learning and abstracting newly generated understandings towards solving the problem (Savery, 2006). Instructors take the role of tutor, and guide students by facilitating group discussion and supporting their engagement in deep learning. As PBL emphasizes students' self-direct learning, the possible ideal learning outcome is deep learning. Deep learning is a learning approach that highlights students' active participation and establishment of student insights towards problems (Spencer & Jordon, 1993; Chin & Brown, 2000). PBL supports deep learning by presenting a problem as complex 'whole', and by maintaining a focus on both dialogic and self-direct learning (Hmelo-Silver, Chernobilsky, & Jordan; 2008). Instead of providing only instructions, instructors support establishment of students' insights by maintaining their role as facilitators.

Instructors in PBL are called facilitators and/or tutors. They provide scaffolding by engaging in a repertoire of strategies, which include open-ended questioning, revoicing, encouraging summarizing, hypothesis generation and evaluation, creation of learning issues, and consensus building based on the activities in the student discussion (Hmelo-Silver & Barrows, 2006). Because PBL problems are specifically designed to be ill-structured and complex, they require a high degree of support and interaction with the tutor to help scaffold the learners in managing the complexity of the problem and supporting the collaborative learning process (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006).

As an instructional model, PBL was designed to be implemented with a low student to teacher ratio, making facilitator's attention a critical factor in determining resources costs and scalability (Albanese & Mitchell, 1993). Facilitating multiple PBL groups is a challenge, but can be supported by activity structures in asynchronous environments.

Our research is situated in a medical context on how to deliver bad news to patients, particularly in cross-cultural settings. Prior research demonstrated that we could effectively use synchronous tools for a PBL on delivering bad news that connected medical students in Hong Kong with medical students in Canada (Lajoie et al., 2014). However, synchronous models were challenging to implement across time zones and required a facilitator for each group, thus, in the current study addresses how to accomplish this asynchronously. Asynchronous communication allows students additional time to develop more substantial arguments before sharing, which may be helpful for some PBL tasks (reporting results of self-directed learning), but challenging for others, such as negotiating meaning.

With asynchronous discussions, it is increasingly possible for a facilitator to support many groups given the slower pace of the discussion and the data that can be made available from online environments. When tracking with multiple groups, the information a facilitator need is really high. Applying visualization tools can inform instructional decision-making by providing summarized data of students' participation that are generated from their real-time activities (Siemens & Baker, 2012). To enable this kind of facilitation to support deep learning, we developed a two-layered support system coined HOWARD (Helping Others With Argumentation and Reasoning Dashboard) to support both the student learning activity and the facilitator's instructional decisions. Here we focus on the facilitator layer.

The purpose of our study is to investigate the instructors' understanding and use of dashboard visualizations in PBL to promote deep learning. There are two research questions of the study: (1) How do PBL facilitators understand and scaffold students' activities under the assistance of dashboard visualizations in asynchronous online PBL? (2) What challenges facilitators faced and possible suggestions for future direction in designing asynchronous PBL environments?

2. HOWARD: An instructional dashboard to support PBL

The HOWARD environment includes with built-in learning tools for students (Fig. 1) and learning analytics visualizations for facilitators (Fig. 2). Here we briefly introduce the functional use of each section of the interface. The student interface consists of 3 sections. A video archive (Fig. 1-1.) provides a set of video clips to introduce the tool, the protocol for delivering bad news, and the video case that serves as the problem context. In addition, two contrasting video cases take place in Hong Kong and Canada separately to stimulate students to think about the cultural difference in communication. A one-level threaded-discussion forum used as a chat space for students to have free discussion and brainstorm ideas (Fig. 1-2). A PBL whiteboard (Fig. 1-3.) is a metacognitive scaffold, designed to communicate the PBL tutorial process of identifying problem facts, ideas for solutions, and issues that students need to learn more about. This supports monitoring and evaluations as ideas are visible and open for discussion, negotiation, and revision (Collins, 2006). This is particularly important for promoting deep learning.

The instructor dashboard includes several types of visualizations that were designed to help the instructor to track cognitive and social process occurring in multiple groups that enhance and promote deep learning. Fig. 2 shows the instructor dashboard for a single group. When multiple groups are present, these dashboards can be tiled together in a single screen. The instructor can then choose to zoom in to a single group as shown. A pie chart indicates the percentage of individual's participation within a group (Fig. 2-1). Two progress bars present group progression by counting the total text output from group members and the percentage of tasks completed (Fig. 2-2). In the middle, a newsfeed updates status of both students' and instructors' action with marked time and types of action (Fig. 2-3). By mousing over certain actions, a pop-up window appears and displays the related output of that action. A social network analysis graph depicts the interaction and its density among participants, allowing the facilitator to get a sense of participation equity (Fig. 2-4). A word cloud is generated from all of the participants' text responses and emphasizes the words in relation to frequency to provide an indicator of semantic content (Fig. 2-5).

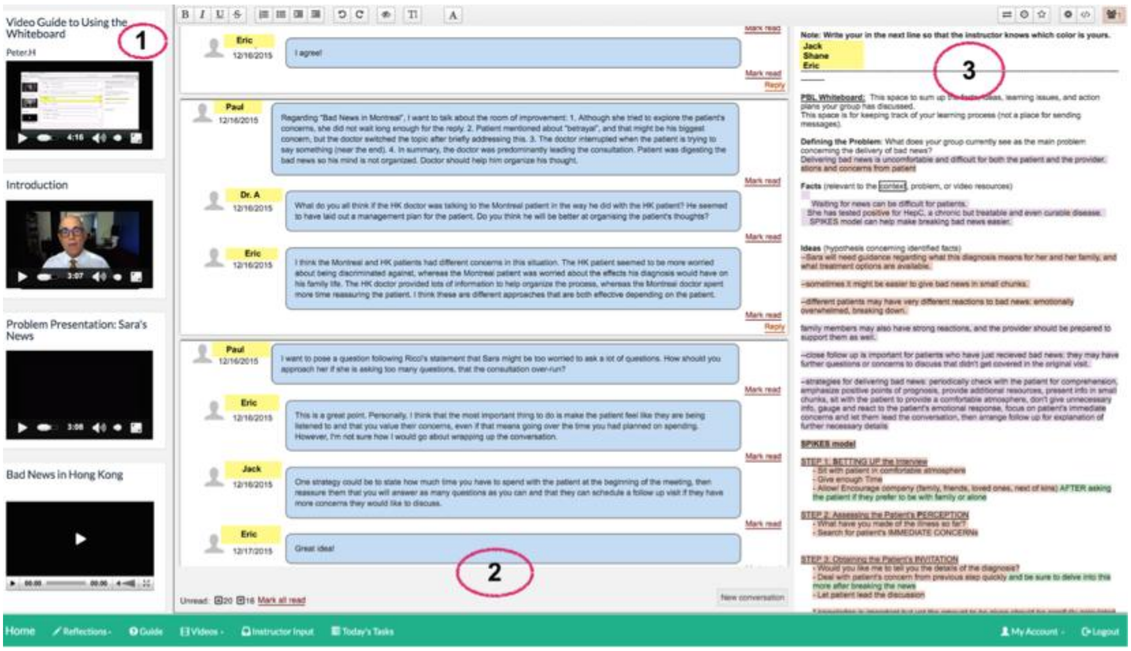

Fig. 1. Student interface to support collaborative learning

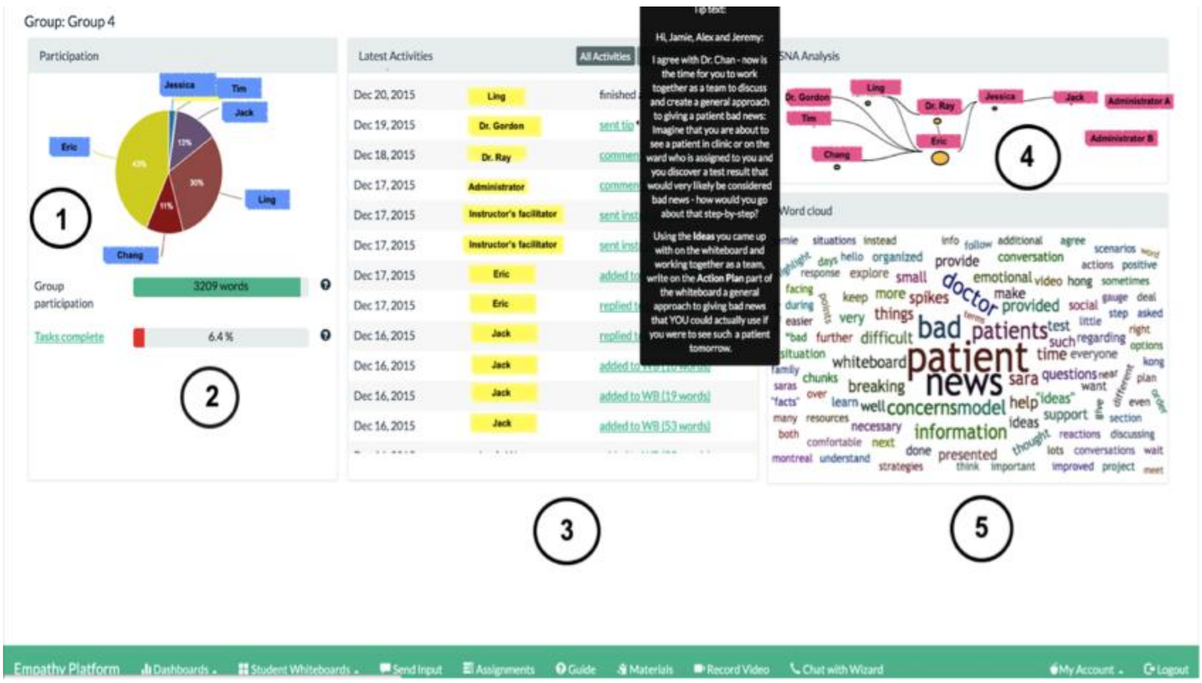

Fig. 2. Instructor dashboard with the use of visualizations

3. Method

Participants. Seventeen students (6 from a Hong Kong medical school and 11 from a Canadian medical school) participated in a two week long PBL workshop on delivering bad news. Initially, they were divided into 4 groups, with two facilitators: Dr. Ray from Hong Kong and Dr. Gordon from Canada each facilitating two groups. However, due to early technical difficulties and later schedule conflicts, only 10 students (3 from Hong Kong and 7 from Canada) remained active participants. To create critical mass for collaborative activities, we regrouped participating students into a single group with both facilitators taking turns in facilitation.

Instructional Design. In HOWARD, students were introduced to the video case of a patient who was waiting to hear about an infectious disease diagnoses. The learning objectives of HOWARD are to help students to develop communicative skills to deliver unfavorable news to patients and generate multiple solutions to deal with such difficult situations. Students were assigned to different groups to participate in a modified PBL learning cycle. This learning cycle is an interactive process that 1) participants post and reply to others' comments to brainstorm and exchange ideas in a discussion forum. 2) To compare two contrasting scenarios cases and make annotation on specific moments to lead more context-relevant discussion. 3) To identify key factors and summarize negotiated actions in the group whiteboard.

Data Sources and Analysis. We collected and analyzed two types of data: instructors' post interviews and raw log data. To help support deep learning in online PBL, facilitation is key to helping students engage productively with each other and content. Thus our purpose is to investigate the facilitator's understanding of the dashboard visualizations, the initial analysis is focused on facilitator's history and experience of using the dashboard. The interviews were open coded to identify themes related to facilitator experience. To help understand what was visible to the facilitators, we used the student log data. We distinguished student log data into two types: students' learning activity as input, such as watching video, and students' text as output, such as writing in whiteboard.

4. Findings

As mentioned above, HOWARD dashboards (for instructors only) are designed to inform facilitators to support students' deep learning. Understanding how facilitators gain awareness of their students' actions through interactive visualizations may help us to know whether the dashboards present sufficient and productive information for facilitators to support deep learning by provide appropriate instructional support and scaffolds. We present four preliminary findings based on the purpose of our study in following sequence: 1) the students showed some evidence of deep engagement— the soliloquy, but 2) it was intermittent— and the instructors only focused on visible output and not necessarily the process data and the evidence for that is there and 3) this was partly because a) too many things to visualize on the dashboard and b) they did not understand how to interpret that.

First, the soliloquy responses from some students, though rare, indicated insightful personal understanding and emotional engagement in breaking bad news. Facilitators anticipated such insightful comments that may indicate the development of professional thinking as doctors. For example, Dr. Gordon noticed an interesting post from a student and commented:

> *It is a pretty sophisticated answer. He said, 'look, you know, you are asking us compare the two sessions, but there two different patients with two different concerns.' I like this answer; it highlighted the right way to give. There are general principles of giving bad news, but they have to be adjusted and applied to the individual patient.*

Second, though students spent more time on learning activity than producing output, facilitators largely valued students' output as evidence of engagement to track students' participation in asynchronous online PBL. The average rate of students' output (6.09 per day) as well as the interval between outputs influenced facilitators' understanding of students' participation and affected how facilitators made instructional decisions. The waiting time of output also led the facilitators to be unaware of students learning activities if they didn't provide any output. As Dr. Ray stated:

> *I need to wait for a day before I can get a response from that person... I will ask all the questions that I could, all in one go, because I know I need to wait for another day before I get some responses from the students.*

Third, (a) facilitators emphasized conversation building to develop collaboration and promote participation while the dashboard didn't communicate such messages. As Dr. Gordon noted, "*as a tutor, asynchronously and intermittently jumping into conversations, the students are doing the same thing. They are jumping into an interrupted conversation.*" This conversation building seems to relate closely with the interval for posting output. In general, visible student output was intermittent, and some days without any output, as Dr. Ray noted, "*sometimes, I find it difficult to build up a dialogue with such a lengthy wait.*" Lacking of sufficient timely output, facilitators demonstrated a challenge to provide just-in-time facilitation to students. (b) We found that facilitators didn't make functional use of the visualizations to apply in instruction. They recognized the function of some tools, such as news feed to identify running activities. As a whole, it seems that this rich dashboard overloaded facilitators, which they didn't fully understand how to use each of the tools. According to Dr. Ray, "*I took at it (SNA) just to see who has a bigger circle, I don't really know how to make better functional use of it.*" This comment echoed by Dr. Gordon who stated that each visualization tool didn't have a specific focus related with instructional decision-making.

5. Discussion

The HOWARD dashboard was designed to help facilitators promote collaboration and engagement in an asynchronous online PBL environment by providing data to support their use of appropriate instructional strategies. The value of our study is to investigate and analyze the use of visualizations in asynchronous PBL to inform facilitators and enhance instructional process. In addition, we examined the applicability and effectiveness of new technological tools: the visualizations in PBL settings. Based on our finding, future research will investigate how we can better provide the right data that instructors need in ways that support their use of appropriate strategies to support deep learning and engagement, particularly as they facilitate multiple groups in collaboration.

In conclusion, we need to figure out what is the most essential data to inform instructional decisions 1) that support deep learning under conditions of intermittent and sometimes long posts, and 2) that we may need to help the facilitators understand visual representations that provide that data.

References

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*(1), 52–81.

Chin, C., & Brown, D. E. (2000). Learning in science: A comparison of deep and surface approaches. *Journal of Research in Science Teaching, 37*(2), 109–138.

Collins, A. (2006). Cognitive apprenticeship. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 47–60). New York: Cambridge University Press.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266.

Hmelo-Silver, C. E., & Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 21–39.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99–107.

Hmelo-Silver, C. E., Chernobilsky, E., & Jordan, R. (2008). Understanding collaborative learning processes in new learning environments. *Instructional Science, 36*(5/6), 409–430.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86.

Lajoie, S. P., Hmelo-Silver, C. E., Wiseman, J. G., Chan, L., Lu, J., Khurana, C., Cruz-Panesso, I., Poitras, E., & Kazemitabar, M. (2014). Using online digital tools and video to support international problem-based learning. *Interdisciplinary Journal of Problem-Based Learning, 8*(2), 60–75.

Savery, J. R. (2006). Overview of PBL: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning, 1*, 9–20.

Siemens, G., & Baker, R. S. (2012, April). Learning analytics and educational data mining: Towards communication and collaboration. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 252–254). ACM.

Spencer, J. A., & Jordan, R. K. (1999). Learner centred approaches in medical education. *British Medical Journal, 318*(7193), 1280.

Extended concept mapping to support problem solving in a computer-based learning environment

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Abstract: Concept mapping has been widely used to foster meaningful learning by graphical representation and communication of complex ideas. With a focus on conceptual understanding, traditional concept mapping is found to be inadequate in supporting complex problem-solving tasks especially in eliciting and representing the process of applying knowledge to practice. This study explored a computer-based cognitive-mapping approach that extended traditional concept mapping by visualizing a set of key elements of cognition in both problem-solving and knowledge-construction perspectives. The approach was used by medical students to elicit complex thinking and actions when working with clinical diagnostic problems in a simulated environment. It aimed to facilitate systematic thinking and meaningful reflection in solving problems and constructing knowledge from the experience. The results showed the effects of the approach in improving the problem-solving performance, although no clear effect was found on improving the subject knowledge.

Keywords: Problem solving; Concept mapping; Computer-based learning environment

1. Our study and findings

1.1. Background

Concept mapping, a way of representing knowledge in graphical formats, has been widely used as a teaching and learning strategy. In a concept map, ideas are represented as a set of concepts and the relationships between the concepts (Novak & Musonda, 1991). By representing information both verbally and spatially, concept mapping may support the comprehension of complex concepts by externalizing and communicating abstract ideas, and help knowledge retention by capturing central ideas. It also has a potential to enable effective cognitive processes by organizing pieces of knowledge into a schematic structure and utilizing the brain's capacity to process images faster than text.

Concept mapping is supported by meaningful learning theory, which emphasizes learning by making meaning of the content instead of by rote. Meaningful learning takes place when learners deliberately seek to relate and assimilating new concepts with prior knowledge into a systematic structure (Ausubel, 1963). Concept mapping has been used as a teaching and learning strategy primarily for learners to demonstrate their conceptual understanding as well as for teachers to assess students' understanding. The literature has reported the advantages of concept mapping in fostering in-depth understanding, knowledge retention, and high-order thinking by enabling learners to construct, communicate, and reflect on their understanding and manage cognitive processes (Nesbit & Adesope, 2006).

In addition to conceptual learning, concept mapping has been introduced to learning in problem-solving contexts. Nevertheless, concept mapping alone is found to be inadequate in supporting complex problem-solving tasks especially in eliciting and representing the process of applying knowledge to practice (Stoyanov & Kommers, 2008). Learning in problem-solving contexts often involves complex cognitive processes such as exploration with information in multiple aspects, integration of problem information and domain knowledge, and reasoning with interactive elements. These processes are often tacit and cannot be easily captured and mastered by students (Jonassen, 1997). The complexity of such processes may generate heavy cognitive load to learners, making it difficult to achieve desired learning outcomes from the experience (Hmelo-Silver., Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006).

According to the cognitive apprenticeship model, carrying out a complex task usually involves implicit processes; it is critical to make such processes visible for novices to observe and practice with expert help (Collins, Brown, & Holum, 1991). However, given the contextual and dynamic nature of actual problem-solving practice, it is difficult to capture the essence of the problem-solving experience and elicit the complex ideas in a meaningful way. Such difficulty is often underestimated by instructors or experts for whom many of the requisite processes have become largely automatic or subconscious because of their experience and expertise. While computer-based cognitive tools have been promoted to support thinking in complex problem situations (Lajoie & Derry, 1993), there is inadequate knowledge of how the complex, implicit processes can be externalized in a way that leads to desired learning outcomes.

This paper discussed the exploration of a computer-based cognitive mapping approach that extended traditional concept mapping with a view to helping learners to externalize complex thinking and actions when they worked with problems in a simulated environment. Medical education was selected as the domain for the study, as problem-solving experience is regarded as crucial to learning and expertise development in this field. Nephrology, the study of kidney function and problems, was selected as the learning subject because of its complexity. Three empirical studies have been carried out to analyze the effects of the approach on learning with simulated clinical problems in a computer-based learning environment.

1.2. How to externalize complex cognitive processes in a problem context?

The problem-solving performance is found to be influenced by both problem-solving and reasoning skills as well as the subject knowledge. The former concerns the hypothesis-driven reasoning method typically used by novices to solve problems, i.e., reasoning by generating and testing hypotheses to account for the data (Patel, Arocha, & Zhang, 2005). The latter concerns not only specific concepts or principles, but also the organization of knowledge into a systemic structure for meaningful understanding and flexible application (Gijbels, Dochy, Van den Bossche, & Segers, 2005). It was found that experts' ability to reason and solve problems heavily depends on their well-organized knowledge, which reflects a deep understanding of the subject, while novices usually lack sufficient or systemic knowledge and rely more on general problem-solving skills (Bransford, Brown, & Cocking, 1999). Further, new ideas developed from the practice are difficult to retain unless they are articulated and anchored to an underlying network of understanding.

Based on the above concerns, we claim that externalizing the essence of the learning experience in problem-solving contexts should take into account two perspectives—problem solving and knowledge construction. *Problem solving* focuses on higher-order cognitive activities for exploration with problem information and formulating and testing hypotheses based on the information, mainly from a *procedural* perspective. *Knowledge construction*, on the other hand, focuses on constructing the knowledge underlying the problem-solving process or new ideas derived from the practice, mainly from a *conceptual* perspective. Accordingly, a dual-mapping approach was proposed by integrating both problem-solving and knowledge-construction perspectives in making cognitive processes accessible to learners when they worked with clinical problems (Wang, Wu, Kinshuk, Chen, & Spector, 2013). By eliciting a set of key cognitive elements of the learning process and representing them in a computer-based cognitive map, this approach aimed to foster deeper learning via visualizing and scaffolding complex thinking and actions in a problem context.

The proposed approach was implemented in an online learning system, which involved a simulated problem context and a dual-mapping cognitive tool. As shown in Fig. 1, the simulated problem context allowed learners to select a case from the case library, interact with the case to access initial information, and activate relevant actions to obtain further information of the case.

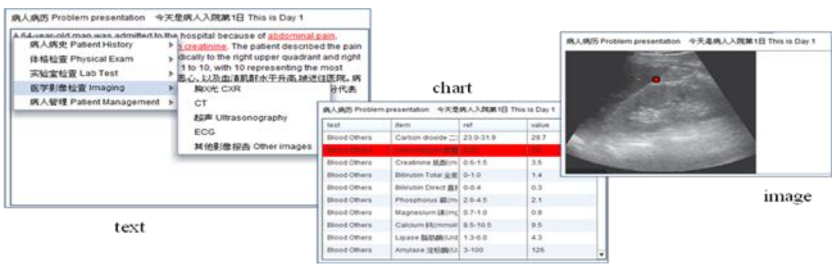

Fig. 1. Simulated problem context

The cognitive mapping tool enabled learners to externalize their problem-solving and knowledge-construction processes when working with clinical problems. As shown in Fig. 2, learner represented their problem-solving process in a procedural map containing critical information, generated hypotheses, and reasoning links for justifying or rejecting a hypothesis; and represented the knowledge-construction process in a conceptual map that contains a set of key concepts and the relations between the concepts.

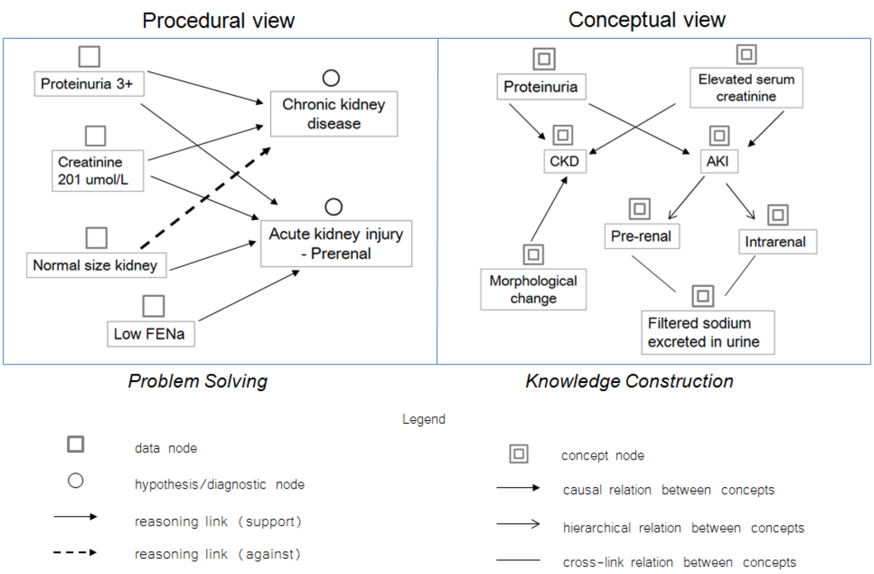

Fig. 2. Dual-mapping cognitive tool

1.3. Effects of the computer-based cognitive mapping approach

Empirical studies were carried out with students from medical schools in east China to examine the effects of the cognitive mapping approach. The analysis of the effects of the proposed approach would not likely to produce reliable and meaningful results unless this approach is properly implemented to the extent that learners find it acceptable. Accordingly, Study 1 made an initial evaluation of the approach using a one-group pretest-posttest design. Significant pre-post improvement was found in the learning products (cognitive maps) and test scores in both problem-solving and knowledge construction processes after the learning with four clinical cases in four weeks. The students found the cognitive mapping approach attractive and useful; however, they commented that some operation of the cognitive mapping tool could be simplified and some interface of the system was not user-friendly. Necessary refinement was made to the system for Study 2. Students were found to make significant pre-post improvement in Study 2; meanwhile, they gave further comments on improving the tool and the interface, and requested detailed instruction on the learning process. Some students mentioned that they usually relied on complete information provided by the teacher in diagnosing a clinical case, rather than using progressive search to explore the problem in this study.

After further improvement of the system and pedagogical support on the learning process, Study 3 was carried out using a control group design. The experimental group used the cognitive mapping approach, while the control group used a note-taking approach, both implemented in the computer-based learning environment. Students in both groups were instructed how to use the given approach to articulate their thinking and actions with a focus on five key aspects: data capture, hypotheses formulation, reasoning with justifications, concept identification, and concept relationships. The results showed that students in the experimental group outperformed those in the control group in the problem-solving process, but no significant difference in the knowledge-construction process and knowledge test.

2. Experienced challenges and relevant strategies

We have experienced several challenges in the studies. First, although relevant theories offer guidelines for learning in problem contexts, it is difficult and needs substantial effort to explore appropriate methods to support complex cognitive processes in problem-solving contexts. A review of the literature cross multiple disciplines is important for developing sufficient understanding of related issues.

Second, the design, implementation, and analysis of a computer-supported approach to learning in a complex problem-solving context require substantial domain knowledge and expert support. We have closely worked with medical experts, instructor, students, and technical developers throughout the project, especially in development of the learning program, assessment methods, and the learning system.

Third, revealing complex processes using a cognitive tool may place high demand on learners' capability to integrate multiple forms of thinking into a complex weave of interrelated concepts. To reduce the cognitive demand of representing the complex process, a set of key elements of cognition was proposed to scaffold the cognitive mapping process. To minimize additional learning effort on using the approach, we iteratively refine the system and the tool and provide necessary instruction on the learning process in light of learners' comments and experts' suggestions.

Fourth, summative assessment was found to be inadequate for assessing learning in problem contexts. We have searched additional literature for performance-based measures to examine the learning outcomes (Linn & Chiu, 2011; Gijbels, Dochy, Van den Bossche, & Segers, 2005). The rubrics used for assessing the learning products in our studies involve five components: data capture, hypotheses formulation, reasoning for justifying or refuting hypotheses, concept identification, and concept relationships. The first three items reflect the problem-solving process, while the other two reflect the knowledge-construction process. In addition, studies on representations of mental models and cognitive processes with computer-based tools provide insight into formative assessment of learning in complex and ill-structured problem domains (Spector, 2006).

Fifth, the finding of no clear effect of the approach on improving the construction of subject knowledge urged us to reflect on our study and research design. While concept mapping may promote meaningful learning, self-constructed concept maps will pose a high demand of learners' capability to analyze and externalize knowledge and the underlying structure, which is challenging in problem-solving contexts. These issues will be taken into account in further studies.

3. Conclusion

Learning through problem-solving involves complex processes that are not accessible to students. It is important to investigate how such complex, implicit processes can be externalized in a way that leads to desired learning outcomes. This study explored a computer-based cognitive mapping approach that extended traditional concept mapping with a view to helping medical students to externalize a set of key elements of cognition when working with clinical problems. The approach aimed to support deeper learning by visualizing and scaffolding systemic thinking and meaningful reflection in performing complex problem-solving tasks. The results showed the effects of the approach in improving learners' problem-solving performance by comparing it to a semi-structured note-taking approach. Further studies are needed to examine the potential of the approach especially in supporting the construction of subject knowledge from the experience.

References

Ausubel, D. (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: brain, mind, experience, and school*. Washington, DC: National Academy Press.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator, 15*(3), 6–46.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research, 75*(1), 27–61.

Hmelo-Silver., C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99–107.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*, 65–94.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86.

Lajoie, S. P., & Derry, S. J. (1993). *Computers as cognitive tools*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Linn, M. C., & Chiu, J. (2011). Combining learning and assessment to improve science education. *Research & Practice in Assessment, 6*, 5–14.

Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research, 76*(3), 413–448.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28*(1), 117–153.

Patel, V. L., Arocha, J. F., & Zhang, J. (2005). Thinking and reasoning in medicine. In K.J. Holyoak (Ed.), *Cambridge handbook of thinking and reasoning* (pp.727–750). Cambridge, UK: Cambridge University Press.

Spector, J. M. (2006). A methodology for assessing learning in complex and ill-structured task domains. *Innovations in Education and Teaching International, 43*(2), 109–120.

Stoyanov, S., & Kommers, P. (2008). Concept mapping instrumental support for problem solving. *International Journal of Continuing Engineering Education and Lifelong Learning, 18*(1), 40–53.

Wang, M., Wu, B., Kinshuk, Chen, N. S., & Spector, J. M. (2013). Connecting problem-solving and knowledge-construction processes in a visualization-based learning environment. *Computers & Education, 68*, 293–306.

The design of scaffolding and fading: Research issues and challenges

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Abstract: The literature shows that question prompts are a powerful strategy in scaffolding ill-structured problem solving. However, little research has been done to understand the mechanism of fading and the effect of fading (e.g., when and how to withdraw scaffolding). Therefore, we designed an experimental study to investigate the effects of both scaffolding and fading on learners' ill-structured problem solving performance, particularly through the lens of constructing arguments, which is an important process in ill-structured problem solving. The results showed that the students who received faded scaffolding did not perform significantly different from the students who received continuous scaffolding. In this workshop, we will share some of the issues we have encountered for this study and some of the strategies we used to address the challenges.

Keywords: Design; Scaffolding; Fading; Ill-structured problem solving; Challenges

1. Point 1: Our own research results

The scaffolding literature indicates that fading out scaffolding is an inseparable part of the scaffolding process (Lajoie, 2005). Despite its importance, fading has often been overlooked in the scaffolding literature (Pea, 2004). Some research suggests that scaffolding should be naturally faded or removed when learners acquired desired skills or concepts (e.g., Pea, 2004; Puntambekar & Hubschur, 2005). One of the main issues related to fading is associated with the design of fading mechanisms. The literature indicated that most of the withdrawing scaffolding is achieved through "passive fading", which means when students no long use the scaffolds provided to them for their voluntary use, it is assumed that passive fading has taken place. The other kind of scaffolding is by design, as found in some of the studies in which scaffolding was provided for a fixed period of time and then it was intentionally removed (e.g., Bulu & Pederson, 2010; Lai & Law, 2006).

The past research shows that the question prompts have a great impact on learners (transient – when the scaffolds are on) (e.g., Ge, Planas, & Er, 2012). However, we do not really understand the mechanism of fading, nor the effect of fading (e.g., when and how to withdraw scaffolding). Therefore, we designed an experimental study to investigate both effects of scaffolding and effect of fading on learners' ill-structured problem solving performance, particularly through the lens of constructing arguments, which is an important process in ill-structured problem solving. Although some researchers have explored the issue of fading (e.g., Bulu & Pederson, 2010; Lai & Law, 2006), additional research is needed to understand how to best remove scaffolds as students become more capable to address the complexities of a problem and become more competent in solving ill-structured problems.

In this workshop, we are going to share some of the issues and challenges we encountered in our effort to conduct an experimental study about scaffolding and fading. The study investigated the effects of embedded prompts as a scaffolding mechanism to support learners in their ill-structured problem solving processes in an open-ended learning environment. Meanwhile, we also examined the effects of withdrawing the prompts on learners' ill-structured problem-solving performance, specifically focusing on the process of constructing arguments.

The results suggested that the quality of students' arguments differed in three facets of argumentation: *initial, counterargument,* and *rebuttal*. Students performed significantly better overall in the area of initial argumentation than the areas of counterargument and rebuttal. The results also showed that the students who received faded scaffolds did not perform significantly differently from the students who received persistent scaffolds; in other words, the two groups performed equally well, which was what we had hypothesized. Yet, we were left wondering what these results could imply, which urged us to move forward with additional data collection in the future. The results of this study have raised further questions and challenges for both research and design regarding effective scaffolds and fading using question prompts, which we will share at the workshop.

2. Point 2: Experienced challenges

There are a number of challenges we encountered while designing this study. Questions such as *what to withdraw*, *when to withdraw*, and *how to withdraw*, arose during the design of this study. Specifically, we were faced with the following challenges: (1) methodological considerations, and (2) contextual constraints or limited resources.

Methodological considerations

In order to understand the roles and mechanisms of scaffolding and fading, we asked ourselves the following questions:

1) What is considered withdrawing?
2) How can we design a learning environment with appropriate scaffolding and gradual fading? What scaffolds are to be withdrawn and how to withdraw them?

3) How can we effectively capture withdrawing effect through an experimental design?

Contextual factors

In addition, we were also challenged with some other issues that were related to the design of the study, including but not limited to the following:

- Identifying sample pools and concerns with sample size
- Recruiting participants
- Identifying instructors who are willing to support our study by allowing us to use their classes, analyze content domains, select tasks for the study, and develop scaffolds (i.e., prompts)
- Selecting appropriate tasks that are of reasonable complexity but limiting the scope to the course curriculum.

3. Point 3: Main strategies

The following section provides details about our strategies to approach the experimental design, recruiting participants, identifying domain experts, selecting tasks, and developing scaffolds.

The study design: Types of prompts, fading schedule, and treatment-control groups

To understand the role of scaffolding and address the challenges mentioned above, we designed an experimental study by assigning participants randomly into two groups: (1) continuous scaffolding and (2) fading scaffolding. The continuous scaffolding group received both problem-solving prompts and reflection prompts in Week 1 and Week 2, but the fading scaffolding group received both types of prompts in Week 1 but only reflection prompts in Week 2. Both types of scaffolding were withdrawn in Week 3. We were hoping that by using two different types of prompts, we were able to withdraw one type of prompts at a time, and by this design it would allow us to capture the effects of fading by comparing the two groups across time. The examples of the prompts are shown in Table 1, and the fading schedule is shown in Table 2.

Table 1
Types of prompts & sample prompts

Types of prompts	Sample prompts
Problem-Solving Prompts	*What are the primary variables in the problem?* (Prompting for problem representation)
	Briefly explain how your solution will work to solve this problem. (prompting for generating solutions)
Reflection Prompts	*How do you justify your decision?* (Prompting for making justifications)
	Am I on the right track? (prompting for monitoring and evaluation)

Table2
Fading schedules

Week/ Condition	Persistent Scaffolding	Fading Scaffolding
1	Problem solving Prompts & Reflection Prompts were given	Problem solving Prompts & Reflection Prompts were given
2	Problem solving Prompts & Reflection Prompts were given	Problem solving Prompts were given
3	No prompts were given	No prompts were given

Building rapport with domain experts and recruiting participants

To overcome the difficulty of recruiting participants for the study, we relied on our connection and to gain buy-ins. One of the co-authors, who had built a good rapport with an instructor teaching a business class entitled Sales Management, which had a relatively nice number of students. He agreed to help us implement the study by allowing us to use his course and to integrate the tasks in his curriculum. Thus, the issue of participants was successfully addressed because since we decided to conduct an experimental study, the N was a crucial issue. With the rapport with the instructor established, we gained access to a pool of 60 students who agreed to participate in the study. Fifty-five of the students agreed to participate in the study and completed all the three weeks of tasks for the experiment. It happened that the participants had little exposure to ill-structured problem-solving, so it made it perfect for us to provide scaffolding to them and examine the effects of fading out the scaffolding. All of the participants were junior and senior level marketing students enrolled in a comprehensive university in USA.

Task relevance and integration of experiment with the curriculum

In order to examine the effects of scaffolding and fading, we would need to select a problem with sufficient complexity and ill-defined nature. Since we had the access to the participant pool, we chose three ill-structured sales management problems for students to solve over a period of three weeks (one problem per week). We considered the relevance of the problems for the study to the course curriculum and tried to integrate the study with the curriculum, so all the three problems selected were appropriate for both curriculum and the study. The students had to work through these problems in order to fulfill the course requirement. In these problems, the participants were asked to construct arguments to justify their potential solutions. Argumentation was thus chosen because of its relationships with ill-structured problem-solving (Kuhn & Udell, 2007; Tawfik & Jonassen, 2013). Theorists (e.g. Jonassen, 2011; Nussbaum & Schraw, 2007) argue that there are three specific aspects of argumentation: *initial argument, counterargument,* and *rebuttal.* Initial arguments detail the opening stance for a particular subject. A counterargument describes an additional solution from the initial argument, which may require individuals to articulate their reasons from a different perspective. Finally, a rebuttal requires individuals to weigh both sides of the initial and counterarguments.

Elicit expert model and theoretical framework to guide the development of prompts and rubrics

The researchers worked with the domain experts to developed (1) question prompts, which followed the ill-structured problem-solving process model (Ge & Land, 2003), and rubrics, which were based on Jonassen and Cho's (2011) argument model. Prompts were the main scaffolds for this study, and thus it was essential to develop prompts based on an expert model and literature as our design framework (e.g., Ge & Land, 2003; Jonassen, 1997). Since we already gained the support with the domain expert (the instructor), we were able to elicit questions from him to make expert's thinking visible to the students. Similarly, the argumentation literature served as a theoretical framework to guide us develop the rubrics for coding learners' argumentation. The argumentation artifacts of the participants were analyzed by three researchers using the rubric published by Jonassen and Cho (2011).

4. Conclusion

We were not able to draw conclusions regarding the effects of fading from this study due to the limited sample size and limited time period. The result contradicted with the previous study on scaffolding fading in ill-structured problem solving, which supports the argument that continuous scaffolding group outperformed faded scaffolding group (Bulu & Pedersen, 2010). Given the results of the study, we offer two hypotheses: First, withdrawing scaffolds earlier did not impact students' performance; which means we may withdraw scaffolding earlier. Alternatively, scaffolding may not have worked effectively; so the group that received the full scaffolding the entire period of time may show similar effects as the group that received fading.

Replicate studies with a larger sample and a longer period of treatment are needed to confirm the hypothesis that when learners become more competent in their problem-solving skills, the withdrawal of scaffolding will not affect their performance. In addition, design-based research is needed to seek answers to *what*, *when*, and *how* to provide and withdraw scaffolding. Another issue also worth investigating is if providing stronger scaffolding specifically targeting on a focused area of difficulty may have an effect on students' improved performance; for example, providing relevant and specific support to help students construct a particular type of argumentation (e.g., counter argument and rebuttal) may help them to improve their argumentation skills not only in these two areas, but also in all the areas. In conclusion, the findings of this study have left us with new challenges to deal with for future research.

References

Bulu, S. T., & Pedersen, S. (2010). Scaffolding middle school students' content knowledge and ill-structured problem solving in a problem-based hypermedia learning environment. *Educational Technology Research and Development, 58*(5), 507–529. doi: 10.1007/s11423-010-9150-9

Ge, X., & Land, S. M. (2003). Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *Educational Technology Research and Development, 51*(1), 21–38.

Ge, X., Law, V., & Huang, K. (2012). Diagnosis, supporting, and fading: A scaffolding design framework for adaptive e-learning systems. In H. Wang (Ed.), *Interactivity in* *e-learning: Case studies and frameworks* (pp. 116–162). Hershey, PA: IGI Global.

Ge, X., Planas, L. G., & Er, N. (2010). A cognitive support system to scaffold students' problem-based learning in a Web-based learning environment. *Interdisciplinary Journal of Problem-based Learning, 4*(1), 30–56.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*(1), 65–94.

Jonassen, D. H. (2011). *Learning to solve problems: A handbook for designing problem-solving learning environments*. New York: Routledge.

Jonassen, D. H., & Cho, Y. H. (2011). Fostering argumentation while solving engineering ethics problems. *Journal of Engineering Education, 100*(4), 680–702.

Kuhn, D., & Udell, W. (2007). Coordinating own and other perspectives in argument. *Thinking & Reasoning, 13*(2), 90–104.

Lai, M., & Law, N. (2006). Peer scaffolding of knowledge building through collaborative groups with differential learning experiences. *Journal of Educational Computing Research, 35*(2), 123–144.

Lajoie, S. P. (2005). Extending the scaffolding metaphor. *Instructional Science, 33*(5), 541–557. doi: 10.1007/s11251-005-1279-2

Nussbaum, E. M., & Schraw, G. (2007). Promoting argument-counterargument integration in students' writing. *Journal of Experimental Education, 76*(1), 59–92.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences*, *13*(3), 423–451. doi: 10.1207/s15327809jls1303_6

Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist*, *40*(1), 1–12.

Tawfik, A., & Jonassen, D. (2013). The effects of successful versus failure-based cases on argumentation while solving decision-making problems. *Educational Technology Research and Development, 61*(3), 385–406. doi: 10.1007/s11423-013-9294-5

Fostering social and entrepreneurial innovation in learning through design: Where are we now?

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Abstract: Creative thinking is increasingly emphasized on in the Horizon Report and in the innovation blueprints across countries. We present an evolution of our investigations into design thinking, first in the creative industries and subsequently in two other Science-based subjects. We extend Learning-by-Design to Engle's socio-cognitive-framework to Garud et al's framework, with design thinking, media and formative assessments as the intermediary. We hope to investigate Winograd's vision of what computing will become, in the next ten years with increasing emphases on human-computer interaction beyond functional requirements, to modelling across disciplines. Significance of this research lies in identification of a pedagogical and design research model and the evolution of a context-aware symbiotic ontological recommender model.

Keywords: Social and entrepreneurial innovation; Learning; Design; Creative thinking

1. Background

The Horizon Report (2016), focuses on inculcating cultures of innovation through technology-assisted maker tools/crafting, focusing on design-based innovations. Many design-based research highlight that sustainable systems need to be engaging, adaptive and innovative. How should we design learning systems to be engaging, adaptive and innovative and not incur cognitive overload?

Engagement can be defined in various ways in different disciplines. However, across domains and disciplines, engagement arises when there is flow arising from dialogic inquiry and experimentation amidst problem-solving as defined by Csikszentmihalyi (1990). This is because the foundation for dialogic inquiry, experimentation and problem-solving is the formulation of hypotheses and strategies and if engaged, then it is immersive.

Correspondingly, Winograd (1997) and Sharp, Preece, and Rogers (2007) envisioned human-computer interaction as branching into more diverse disciplines as computing increasingly encompasses user experience. Hence, it becomes crucial to formulate a holistic model of the different aspects of the design and computing ecosystem through interactive theorizing.

In the following, we present our evolution, from Learning-by-Design to Engle's (2006) socio-cognitive framework-cum-design thinking to Garud, Gehman, and Giuliani's (2014) entrepreneurial framework-cum-design thinking, towards engaging, adaptive and innovative thinking. The evolution was not planned by the researchers. They came about due to research opportunities at the time across various universities.

2. Learning sciences: Learning-by-Design (cognitive, middle school, think like Scientists - research skills)

Kolodner's (1994) case-based theory of creativity in design and Goel and Bhatta's (2004) theory of creative design integrating case-based and model-based reasoning shed light on the development of creativity in Scientific design. A cognitive model for middle school children, Learning-by-Design (LBD) aims at teaching children Science and helping students to think like Scientists, through guiding questions. Kolodner (1994) suggests two design cycles: to discover and to experiment. Guiding questions are formulated for each cycle.

In Lee and Kolodner's (2011) curriculum reference model for creative design, we explored strategies to address environmental concerns. The design however, was not carried out.

3. LBD meets Design thinking (socio-cognitive-affective, entrepreneurial, tertiary students, research skills, transfer of learning)

Our next group of students were undergraduate students in the creative industries, which is very market, media and communication-oriented. Hence, we drew from the industry's design thinking practices to broaden the dimensions to encompass entrepreneurial outcomes with hopes of social innovations through sustainable design (our interpretation of Brown and Wyatt's (2007) research on social innovations for the creative industries). Their research highlight that designing for social innovation can lead to surprising positive outcomes, as evidenced through projects such as Teach4America and Girls for Code.

Boyle (1997) and Mayer's (2008) research into multimedia learning for deeper learning and retention highlight that generative processing (deeper learning) has to be contextual and that multimedia plays a key role as tools for testing out hypotheses during prototyping. They emphasize that multimedia learning promotes meaningful/deeper learning by creating questions mapping problem-solution space, and consequently, retention.

3.1. Hypothesis

The question is how to reduce cognitive overload especially in media-rich and interdisciplinary fields and with multi-disciplinary design thinking? We hypothesized that if we can increase cognitive salience by developing epistemic agency, deep associative learning is more likely to occur. Sense-making would become more purposeful and meaningful.

3.2. Design factors/scaffolds

Due to the broadening of dimensions, we grounded the design for increasing cognitive salience via socio-cognitive-affective framing, and embedded formative assessments on design thinking and research skills (the latter similar to LBD). This framework is supported by Bereiter (1995) and Engle (2006). Bereiter proposes that intrinsic/affective factors such as dispositions and beliefs influence learning outcomes. Building on this proposition, we extended LBD's cognitive framework to affective dimensions. Engle's (2006) socio-cognitive framework focuses on theorizing and causal learning aimed at knowledge building and developing epistemic agency.

In addition, Koster's (2004) theory of fun exemplifies creating flow in various contexts involving dialogic inquiry and problem-solving, formulation and reformulation of goals/objectives, strategies and patterns. The theory was originally for games design. In our studies, we focused on game-like thinking, which enables experimentation, pattern recognition and pattern creation.

3.3. Studies in the creative industries and software design and testing (socio-affective-cognitive, knowledge building, epistemic agency, sustainable UX)

From 2013-2015, we scoped our study to youth. Based on the same hypothesis as in Section 4, we aimed to:

a) develop deeper understanding of design and design thinking towards more meaningful learning outcomes and social innovations (sustainable design and user experiences) among youths;

b) increase cognitive access and epistemic agency (Scardamalia & Bereiter, 1994) in view of developing lifelong learning and communication skills via a media-visual approach. A media-visual approach suits Keller's (2010) Motivation theory focusing on Attention (inquiry and perceptual arousal), Relevance, Confidence and Satisfaction.

We carried out of a series of studies in the Malaysian context in the Faculty of Creative Industries, Universiti Tunku Abdul Rahman, Malaysia. Based on the above design factors, all studies shared five common characteristics:

a) all were led by the students' own interests and beliefs in line with knowledge building principles in general and specifically, with regards to the development of epistemic agency;

b) all studies involved experimentations with media to create craft and Web pages;

c) all were guided by each discipline's methodologies;

d) all involved reflective reports to encourage dialogic and reflective inquiry;

e) the evaluation criteria were mainly sustainability and user experience, translated in different forms and methods respective of each discipline. An example of the assessment rubric is in Lee and Wong (2015).

Subsequently, in Lee and Wong (2015), we proposed an initial conceptual framework for developing generative designs for the studies carried out on the creative industries. These are:

a) learning environments and systems need to focus on theorizing and high-fidelity prototyping;

b) focusing on framing and reframing the context/problem in order to derive more alternatives and better solutions;

c) to sustain theorizing, learning needs to be fun and interactive;

d) to be creative, develop multiple perspectives, extend beyond functional designs to designing user experience;

e) design thinking and metacognitive reflective scaffolds as embedded formative assessments need to be integral.

For Software design and testing (Lee, Wong, & Lau, 2015), students were encouraged to use visualize but the focs was on the discipline's own methodologies and there were no reflective reports. We find that:

a) better performing groups who venture across disciplines to broaden their scope of study to cater towards actual market needs and actual significance of their study; exhibiting design thinking concepts and processes although it is not taught explicitly;

b) better understanding of users' needs relating to the ecosystem and objectives to lead to better outcomes;

c) the quality of the design outcome improves more, first, with the use of context and user needs, followed by patterns (model).

Hence, although the research process underlying design across disciplines were scaffolded by each discipline's methodologies, findings were positive in terms of near and far transfer.

3.4. Study on e-commerce in a media-model entrepreneurial framework (sustainable systems development)

In Sunway University (mid-2015 onwards), the aim is to develop a methodology and framework for effective learning of STEM through a more entrepreneurial approach, but still keeping to the aim of inculcating sustainable social innovations among youths. We extended LBD's two cycles and Engle's socio-cognitive-framework to Garud, Gehman, and Giuliani's (2014), still with design thinking, media and formative assessments as the intermediary. We hope to investigate possibilities of Winograd's vision of what computing can become, emphasizing on human-computer interaction beyond functional requirements, modelling across disciplines with design thinking's empathy as primary, translating empathy into user experience and interactions. Our aim is sustainable systems development.

Garud, Gehman, and Giuliani's (2014) narrative entrepreneurial framework contextualizes the development of epistemic agency, as moderated by different conceptualizations of contexts. Learning is an evolutionary process and innovation is contextualized through narratives, as actors and contexts are co-created through performative efforts. An entrepreneurial innovation narrative however, views opportunities as "found" or "made". The actor evolves through a dynamic balance of micro-macro (actor-centric perspective/ context-centric perspective) approaches to multilevel to constitutive approaches (such as those informed by structuration, complexity and disequilibrium theories), with the main aim of developing generalizations/principles.

In our first pilot study, i.e. on e-commerce (Lee & Wong, 2016), we aimed to teach agile methodology and design transfer/transformation. The findings confirmed design factors for generative processing resulting in near and far transfer. Also, students recognized the importance of value propositions and that design means exploring ways to create value. More importantly, the better performing groups designed services based on intangible factors. The element of reflective monitoring and adjusting by the designer stands out as the most important factor in ensuring success. This highlights the importance of adaptive design in terms of learning pathways.

Our subsequent studies include gamification. Gamification is the craft of applying the fun and engaging elements found in games to non-game contexts. It is "Human-Focused Design," as opposed to "Function-Focused Design", (similar to design thinking) and focuses on enhancing user-experience/engagement, due to its game-based/experimental/hypothesis testing roots. At the core of gamification is context-awareness. It thus provides a suitable experimental playground for discovering the applications of STEM in everyday life.

4. Challenges

Organizational support is crucial. Successful prior cases motivate. Building trust is important.

5. Significance of the studies

We hope our work-in-progress will eventually contribute towards the following:

a) development and refinement of our context-aware socio-cognitive-affective model;

b) development of a framework and methodology for effective learning of creative thinking, STEM/STEAM, leading possibly to smart product/systems-service design/innovation.

6. Conclusion

We have presented an evolution of our design-based studies and our findings on design factors/scaffolds, which contribute towards knowledge building, creativity and epistemic agency. Our sample size is small, so the findings are not generalizable yet. We hope our small findings can be applied to improve learning outcomes and to develop more meaningful and sustainable systems, product and services; advancing technology for humanity to transform education and empower learners.

Acknowledgements

Thanks to Multimedia University, Universiti Tunku Abdul Rahman and Sunway University for their support and sincere thanks to Assoc. Prof. Dr. K. Daniel Wong for his comments during the design thinking research.

References

Bereiter, C. (1995). A dispositional view of transfer. In A. McKeough, J. Lupart, & A.

Marini (Eds.), *Teaching for Transfer: Fostering Generalization in Learning* (pp. 21–34). NJ: Lawrence Erlbaum Associates.

Boyle, T. (1997). *Design for multimedia learning*. New York: Prentice-Hall.

Brown, T., & Wyatt, J. (2007). Design thinking for social innovation. *Stanford Social Innovation Review, Winter*, 31–35.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York: Harper Perennial.

Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *The Journal of the Learning Sciences*, *15*(4), 451–498.

Garud, R., Gehman, J., & Giuliani, A. P. (2014). Contextualizing entrepreneurial innovation: A narrative perspective. *Research Policy, 43*, 1177–1188.

Goel, A. K., & Bhatta, S. R. (2004). Use of design patterns in analogy-based design. *Advanced Engineering Informatics*, *18*(2), 85–94.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. New York: Springer.

Kolodner, J. L. (1994). Understanding creativity: A case-based approach. *Lecture Notes in Computer Science, 837*, 1–20.

Koster, R. (2004). *Theory of fun for game design*. NY: Pearson.

Lee, C. S., & Kolodner, J. L. (2011). Scaffolding students' development of creative design skills: A curriculum reference model. *Educational Technology & Society, 14* (1), 3–15.

Lee, C. S., & Wong, K. D. (2013). The role of framing in scaffolding near and far transfer: A case study. In *Proceedings of IEEE 13th International Conference on Advanced Learning Technology* (pp. 401-402).

Lee, C. S., & Wong, K. D. (2015). Developing a disposition for social innovations: An affective-socio-cognitive co-design model. In *Prooceedings of the International Conference on Cognition and Exploratory Learning in Digital Age*. Maynooth, Greater Dublin, Ireland.

Lee, C. S., & Wong, K. D., & Lau, S. B. Y. (2015). Scaffolds and design factors to increase creative outcomes in teaching software design and testing. In *Proceedings of the International Conference on Industrial Engineering and Engineering Management*. Singapore.

Lee, C. S., & Wong, K. D. (2016). E-commerce Web design engineering: Towards discovery of innovation opportunities and product-service co-reification. In *Proceedings of IEEE 16th International Conference on Advanced Learning Technology*. Austin, Texas.

Mayer, R. E. (2008). *Multimedia learning* (2nd Edition). New York: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge building communities. *The Journal of the Learning Sciences, 3*(3), 265–283.

Sharp, H., Preece, J. & Rogers, Y. (2007). *Interaction design: Beyond human computer interaction* (2nd edition). NJ: John Wiley & Sons Ltd.

The Horizon Report. (2016). *Horizon report: 2016 higher education edition*. Retrieved from https://library.educause.edu/~/media/files/library/2016/2/hr2016.pdf

Winograd, T. (1997). From computing machinery to interaction design. In P. J. Denning & R. M. Metcalfe (Eds.), *Beyond calculation: The next fifty years of computing* (pp. 149–162). Berlin: Springer-Verlag.

If you don't tell us, how can we know what we are supposed to do? - A case study of a Grade 5 science community co-constructing collective structures to support sustained inquiry over a school year

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Abstract: In this study, we investigated how a Grade 5 science community co-constructed pragmatic structure in the form of "research cycles "of inquiry to support an emergent and progressive trajectory of knowledge building in a year-long initiative. Qualitative analysis of field notes, classroom videos, and student notebooks elaborated the emergence of research cycles assisted by the teacher. Analysis of student interviews showed how this structure was used and adapted by individual student to position and monitor knowledge progress and plan for further inquiry. Content analyses of student focal questions and online discourse indicated that students moved to more advanced research individually and made more productive contributions in the collective level.

Keywords: Community; Co-constructing; Collective; Structures; Inquiry; Qualitative analysis

1. Our study and results

The purpose of this study is to explore the dynamic process by which a knowledge building community co-construct the pragmatic structure about how to perform their individual and collective work. Such structures are typically pre-defined by the teacher/designer in the form of inquiry procedures and collaboration scripts (Dillenbourg, 2002), which are mainly applied to guide relative short inquiry activities. Such procedure-focused lack high-level agency and dynamics, which are essential creative practices (Zhang, Hong, Scardamalia, Teo, & Morley, 2011). In sustained knowledge building that extends over a long period of time, the process of inquiry cannot be pre-scripted. It becomes imperative for students to take on the high-level responsibility to chart the process of progressive inquiry as progress is made (Scardamalia, 2002; Zhang, Scardamalia, Reeve, & Messina, 2009).

The study was conducted in a grade five classroom with 19 students from upstate New York in 2014-2015. The students investigated human body systems with Knowledge

Forum (KF) (Scardamalia & Bereiter, 2006). Knowledge building practices in the classroom integrated individual and small group reading, whole class face-to-face conversations, individual and small group modeling and demonstrations, and student-directed presentations. Major questions and findings generated through these activities were contributed to KF for continual discourse. During their process of inquiry, with support from the teacher, students reflected on how they had been/should be doing their inquiry and co-generated a model of "research cycles" to guide their work. The research cycle highlighted important actions, including asking question, doing initial research, contributing online, developing initial theories, doing deeper research, revising theories, sharing with the class, leading to deeper questioning (see Fig. 1).

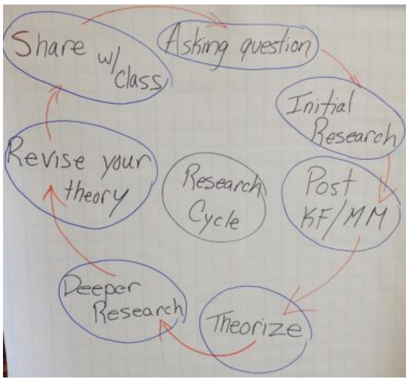

Fig. 1. Collective "Research Cycle"

1.1. The emergence of the collective structure

To understand the emergence of the "research cycles", we conducted qualitative analysis with rich classroom data, including field notes, classroom videos, pictures of students' notebooks, and artifacts created by students. Analysis of these data yielded three main phases involved in the emergence of the research cycles (see Fig. 2):

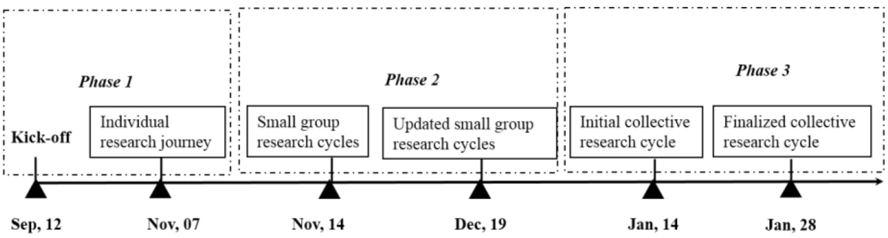

Fig. 2. Evolution of research cycles over a whole school year

Phase 1: Reflection on individual journey of inquiry: In early November, when the teacher noticed students actively commented and built upon each other's ideas, he brought up the concept of research journey. With two questions provided by the teacher, each student reflected reflect on their own learning journey, in terms of where they were now and where to go next. They first shared and discussed their answers in small groups. Then they organized a whole class discussion to share the reflection.

Phase 2: Co-generation and improvement of small group research cycles: Students worked in small groups and generated group-based research cycles according to their individual reflection on research journey and experience in collaborative inquiry. Most of the research cycles generated by small groups included some similar components. Each small group used their own model to reflect on their knowledge building work and decided what they needed to do for deeper inquiry. After gaining deeper experiences with the inquiry process in small groups, the five small groups revisited and updated their research cycles in mid-December, mostly to refine the sequences of the components and rephrase the components (see Fig. 3 and Fig. 4).

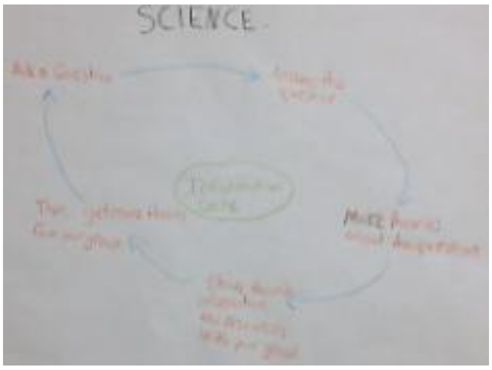

Fig. 3. Original small group research cycle

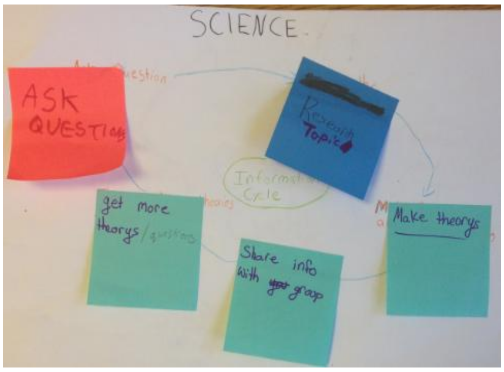

Fig. 4. Updated small group research cycle

Phase 3: Synthesis of small group research cycles into the collective research cycle: In January, the teacher encouraged students to reflect on their research in the past months and develop a collective model of research cycle that everyone can use to guide new research in the spring semester. Students first identified the first three components: asking a question, initial research, and sharing online or in whole class meetings. Then they proposed and included four more components: theorize, research deeper, revise theories, and share within the class (then start over), leading to the collective cycle shown in Fig. 1.

By reflecting on their initial journeys of research as individuals, small groups, and a whole community provided a dynamic social context by which the pragmatic structure of the research process emerged and was reified as formal research cycles. Reflection at the individual level directly connected with students' earlier intuitive way of doing science inquiry and provided the basic components of the inquiry process. The experience of engaging in collaborative inquiry and constructing small group research cycles gave them a chance to review and update their individual "schema" about science inquiry. An initial small group research cycle (see Fig. 3) was drafted by ordering the components from individual reflection and inquiry experience. Small groups changed the order of those components and rephrased them in a more scientific way after the application of it for one month (see Fig. 4). But as their inquiry went deeper, they had the experience to conduct deeper research and revise their existing theories, more components were added to the collective research cycle, to make it as a shared schema for progressive inquiry (see Fig. 1).

1.2. Teacher's strategies in facilitating the emergence of the collective structure

Analysis of classroom talks and interactions revealed two strategies adopted by the teacher in facilitating the generation of the research cycles. First, the teacher actively engaged in the reflection process as a responsive facilitator by asking metacognitive questions to stimulate productive thinking and sharing. In addition, the teacher monitored emergent practices of inquiry in the classroom that appropriated the collective research cycles, and purposefully identified productive examples to make the research journey more accessible for all students.

1.3. Students' adaptive use of the collective research cycle

In order to understand how students used the pragmatic structure in their inquiry, we interviewed seven students about their inquiry at the end of the school year. All the seven students interviewed thought the research cycle was helpful in guiding their knowledge building process. Analysis of their reflective comments on how they specifically used the research cycle revealed two categories: (a) following the cycle; and (b) adapting the cycle for their own use. A few of the students followed all the components in order as they investigated different research topics. Other students modified the collective cycle in different situations.

1.4. Knowledge building achievements in individual and collective level

We coded students' individual focal research questions in September and May with the "Structure-Behavior-Function" framework (Hmelo-Silver, Marathe, & Liu, 2007).The proportions of students' questions differ significantly between September and May (χ^2=14.97, *df*=2, *p*=.001). To measure the collective knowledge advancement, we further analyzed how students made various types of knowledge-building contributions (Zhang et al., 2011) as reflected in their online discourse before and after the emergence of the research cycles. Analysis indicated that before the construction of the collective research cycle, the most visible online contributions posted relatively broad explanatory questions about the body systems and generated intuitive explanations. After the negotiation of the research cycles that systematically highlighted a diverse range of specific knowledge building actions, students had a large number of posts raising idea-initiating questions and idea-deepening questions, elaborating ideas using referential sources of information, using evidence to support or challenge ideas, providing alternative explanations, and connecting and integrating ideas to develop coherent understandings.

2. Experienced challenges

The major challenge we experienced is at the conceptual level. For classrooms to work as knowledge creation communities, students need to engage in sustained inquiry. However, existing design to support inquiry tend to focus on a procedure-based method. This method doesn't contribute to our work in knowledge building context when students' inquiry usually goes beyond short-term inquiry. Therefore, we argue for the need to understand the dynamic social control mechanisms underlying long-term knowledge building practices, particularly, how dynamic knowledge building interactions are formulated, regulated, and continually adapted for sustained productivity driven by students' collaborative input and collective responsibility (Zhang et al., 2009). The other challenge is related to the data collection and analysis techniques during such long-term inquiry.

3. Main strategies

In this study, we are trying to elaborate a reflective structuration framework to understand how long-term dynamic knowledge building practices are formulated and adapted. Beyond metacognitive mechanisms of the individual and interacting minds, the emergent structuration approach further highlights social control structures: social rules and resources that frame and guide ongoing social practice (Giddens, 1984). In a knowledge building community, members make intentional contributions to advance their collective knowledge of value to the community and develop dynamic collaboration with each other (Scardamalia & Bereiter, 2003). Their ways of contributing and interacting give rise to, and are further influenced by, the macro-level, collective structures of their community, including its shared goals, norms, and participatory structures. These collective structures, once emerge, take on a social life, being continually reused, discussed, and modified. Students monitor and regulate their knowledge building practices using the collective control structures as a resource. Such structures signify key properties of their inquiry practices, including: what knowledge goals the community needs to achieve (epistemic structures), how they will achieve the goals (pragmatic structures), and who should do what with whom in their inquiry (participatory structures). By conceptualizing the collective structures into three aspects, we have different focuses at different phases in conducting a three-year design-based research. Our previous study has examined how students co-generated collective wonderings and knowledge goals, as an epistemic structure, to guide their discourse and inquiry and reflect on progress (Tao, Zhang, & Huang, 2015). This study focuses on the one important component of pragmatic structure and further explores the dynamic process by which a Grade 5 science community co-constructed pragmatic structures of inquiry to support an emergent and progressive trajectory of knowledge building in a year-long initiative.

4. Conclusions

The results suggest two-way ongoing interactions between the ongoing knowledge building practices of the members and the collective structures of the community: the collective structures emerge from members' ongoing practices and interactions through reflective monitoring and meta-talks, and become alive and influential through members' subsequent talks about and purposeful use of the structures. The teacher facilitated the multiple cycles of reflective talks, encouraging students to reflectively identify important features of research from their own ongoing knowledge building practices, negotiating the meanings of the components and their connections, while making connections with the practices of expert scientists. Students referred to components of the research cycles in classroom talks to communicate their work, and used the cycles to reflect on what they were doing and what they needed to do in the next steps. They acted in accordance with the research cycles to conduct their research and adapted the cycles flexibly when they needed in specific situations. Through the intentional and adaptive use of the research cycles as a pragmatic structure of inquiry, students conducted sophisticated knowledge building practices individually and as a community.

References

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL: Can we support CSCL* (pp. 61–91). Heerlen: Open Universiteit Nederland.

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems. *Journal of the Learning Sciences, 16*, 307–331.

Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration*. Cambridge: Polity Press.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago, IL: Open Court.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. In *Encyclopedia of education* (2nd ed., pp. 1370–1373). New York, NY: Macmillan Reference.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97–115). New York: Cambridge University Press.

Tao, D., Zhang, J., & Huang, Y. (2015). How did a grade 5 community formulate progressive, collective goals to sustain knowledge building over a whole school year? In O. Lindwall & S. Ludvigsen (Eds.), *Exploring the material conditions of learning: Proceedings of the 11th International Conference on Computer Supported Collaborative Learning* (Vol. 1, pp. 419–426). Gothenburg, Sweden: International Society of the Learning Sciences.

Zhang, J., Hong, H.-Y., Scardamalia, M., Toe, C., & Morley, E. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the Learning Sciences, 20*(2), 262–307.

Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognate responsibility in knowledge building communities. *The Journal of the Learning Sciences, 18*(1), 7–44.

Enhancing students' science learning in a seamless inquiry-based learning environment leveraged by BYOD (Bring your own device)

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Abstract: This paper reports on a one-year study using design-based method to investigate how students in a Hong Kong primary school developed their science knowledge in a seamless inquiry-based learning environment leveraged by BYOD (Bring Your Own Device). The findings show that integrating various apps on BYOD into inquiry-based learning could help young learners advance their science knowledge, and gain a better sense of ownership in learning.

Keywords: Science learning; Seamless; Inquiry-based learning

1. Research background

Research on teaching and learning leveraged by Bring Your Own Device (BYOD) in a seamless learning environment has been gaining popularity in recent years (Falloon, 2015; Lai, Khaddage, & Knezek, 2013). Alberta Education (2012) defines BYOD as a technology model where students bring a personally owned device to school for the purpose of learning. S*eamless learning* refers to the seamless integration of the learning experiences across various spaces (Wong & Looi, 2011). Although current studies on exploring the potentials of using BYOD to promote better learning experiences and enhance engagement across time-space boundaries have been on the rise, rarely explored in primary education is the question of how BYOD integrated with inquiry-based pedagogy in a seamless authentic learning environment can help improve student's knowledge gains. This study aimed at addressing this question.

2. Research methods

The study adopted design-based research (Collins, Joseph, & Bielaczyc, 2004) to examine the impact of inquiry-based pedagogical design with BYOD on primary students' knowledge advancement in authentic contexts. Participants were 28 students in a class of Grade 6, among them 24 brought mobile devices from home, including 10 iPads, 11 Android tablets or smartphones, 2 iPhones and 1 iPod. Four students used iPads provided by the school. The study involved 5 science units with 12 topics.

Three apps, namely Edmodo, Evernote and Skitch, were selected in the pedagogical design. Edmodo is a social learning platform with both web-based and mobile versions. Evernote is a cloud note-taking and archiving application where notes can be taken in text, video and audio modalities that can be accessed anywhere and anytime. Skitch is an extension of Evernote which allows annotation functions, with image and shape editing, and website screenshot captures. In addition, the camera/recording functions on BYOD were used by the students to record their learning process and reflections in picture, and audio and video files.

Based on previous research into inquiry pedagogical design (Hakkarainen, 2003), a seamless inquiry learning model supported by various apps on BYOD was developed (see Fig. 1).

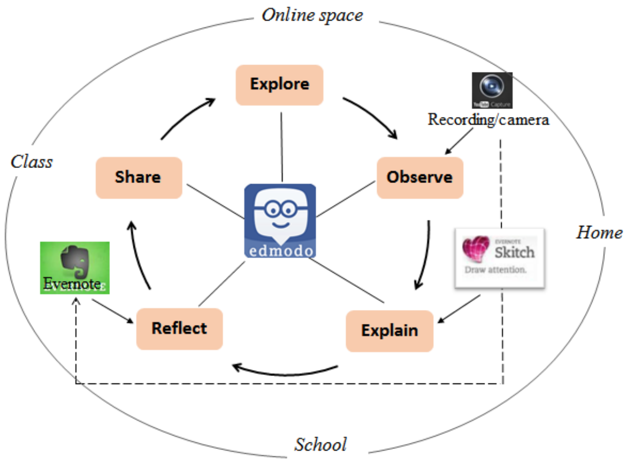

Fig. 1. A seamless inquiry-based learning model leveraged by apps on BYOD

The inquiry-based pedagogical model comprised six elements where students' work in groups: (1) 'engage' in question and hypothesis formation; (2) 'explore' the methods and processes of inquiry; (3) 'observe' the phenomena in the experiment where students collected data using the camera function on BYOD to take pictures or videos; (4) 'explain' the analyses and outcomes of inquiry where students used Skitch app to annotate the pictures for different learning tasks (e.g., Fig. 2); (5) 'reflect' the processes and outcomes of inquiry where students use the Evernote app to make reflections in text, pictures (taken using the camera function), and audio files using the recording function on BYOD; and (6) 'share' the findings and reflections on Edmodo.

The study consisted of 3 iterative cycles shown in Fig. 3. The pedagogical design included inquiry learning activities across home, school, class and online spaces in authentic contexts. The BYOD apps supported inquiry-based pedagogical strategies supported by the apps on BYOD as the intervention of this study. The results of each cycle of intervention were used to clarify research goals and identify necessary refinements in strategies, which in turn, guides the design and implementation of subsequent efforts (Collins, Joseph, & Bielaczyc, 2004).

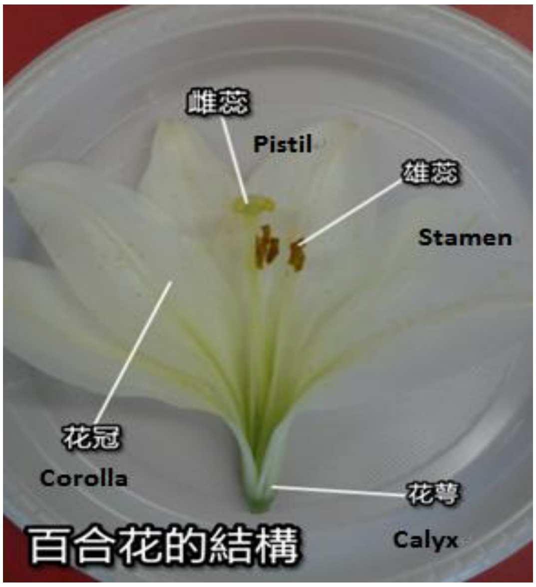

Fig. 2. Group work on the annotated structure of Lily using Skitch app

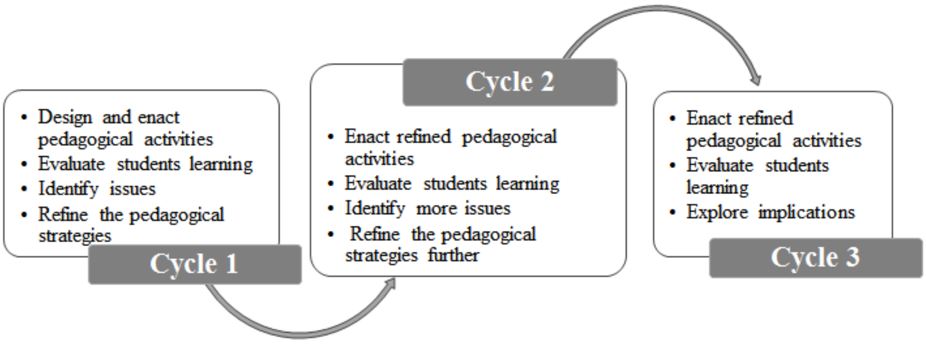

Fig. 3. Three-cycle design-based research

The enactment of the pedagogical activities in each cycle is shown in Fig. 4. Fig. 4 shows that the enactment of the pedagogical activities in each cycle underwent six stages guided by the seamless inquiry-based learning model. These stages were conducted in a cyclic but non-linear fashion. The activities were carried out across four contexts: classroom, home, school lab and an online learning platform – Edmodo leveraged by BYOD.

Various data collection methods were employed, including pre- and post-domain tests with concept maps, student artifacts (postings on Edmodo, postings on Evernote, captured photos, captured recordings, and captured videos), class observations and field notes. Both qualitative and quantitative methods were adopted to analyze data.

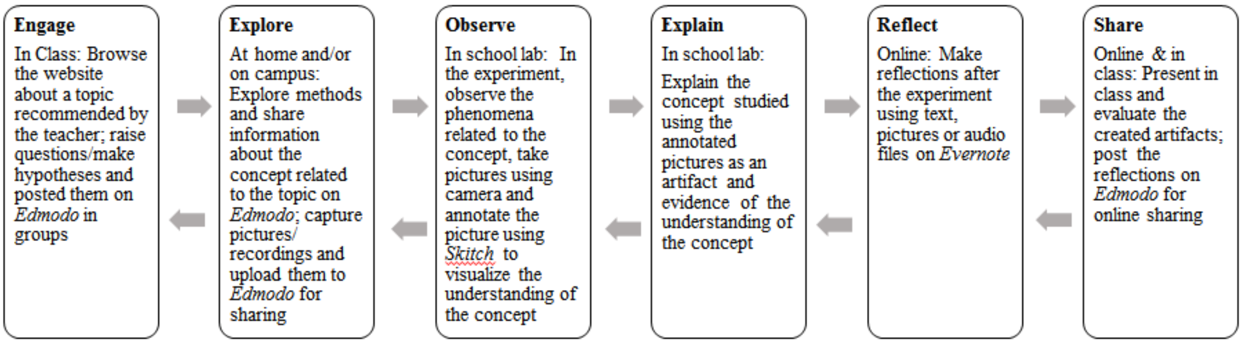

Fig. 4. Implementation of the pedagogical activities in each cycle of the study

3. Research results

The results show that: (1) students gained a better understanding of the science concept and constructed knowledge collaboratively; (2) the integration of apps on BYOD into guided inquiry-based learning might help young learners to advance their content knowledge. The combination of these affordances helped the students gain solid domain knowledge about science concept (e.g., the knowledge about the structure and other knowledge of the Faba bean), which was beyond the 'textbook knowledge'; (3) the three apps of Skitch, Edmodo and Evernote were used interactively in this study by connecting the learning tasks 'seamlessly' which greatly boosted the flexibility, mobility and interactivity of learning at a relatively inexpensive cost (Song, 2016) and facilitated students' personalized learning by setting their own learning goals, beyond the classroom (e.g., extended school) and following their own learning path (Kearney, Schuck, Burden, & Aubusson, 2012). Hence, students maintained a sense of ownership and control over their own learning, which was lacking in prior mobile learning studies where they needed to borrow the devices from school (Song, 2014); (4) students working in groups could take advantage of different types of devices for different purposes, which is rarely found in the existing studies of the literature in primary education. For example, iPads, Smartphones and iPhones were good for taking pictures, iPad and Android tablets were favorable for doing annotations and writing reflections, and iPod was good for making observational recordings. While grouping the students, these functional features of devices needed to be taken into account; and (5) visible artifacts such as photos, text, recordings and video clips documented students' learning process and mediated their learning. Stahl (2002) maintains that tracing individual and group inquiry in multiple spaces can make visible the learning process and outcomes. It is interesting to note that students' skills and engagement in science inquiry were improved, together with deeper content knowledge construction.

To understand better how knowledge construction is accomplished in seamless, mobile technology-supported inquiry learning, a group was randomly selected in their inquiry into the topic of 'structure of seeds' and the development of students' artifacts related to the 'faba bean' was tracked. The students were encouraged to make use of their personal device to engage in the six inquiry learning activities guided by the seamless inquiry-based learning model. The group members carried out the investigation collaboratively. They took pictures of the seed using the camera app on iPad, then labeled parts of the flower (see Fig. 5) using the annotation tool Skitch, on their mobile device. After it, they uploaded their results to the social network platform, Edmodo. The simple annotation tool in Skitch allowed students to show their understanding by labeling the parts of the seed, then share their annotated file on Edmodo as evidence, suggesting that the group members understood the concept of seed structure.

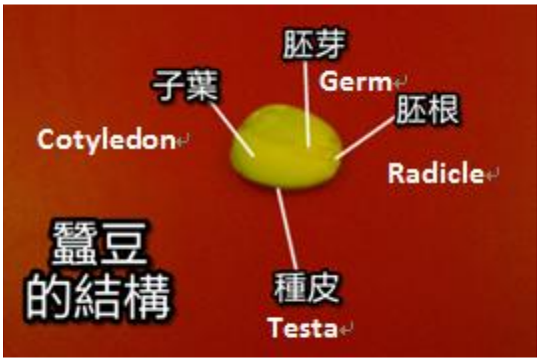

Fig. 5. Group work on the structure of Faba bean

The group members also wrote their reflections on Evernote using their personal device as a tool for knowledge construction. Group member 1 reflected:

> *As I investigated the structure of a faba bean, I looked at the cotyledon and the gemma. Faba bean belongs to dicotyledons because the seeds have two cotyledons and it is a flowering plant. The apps on BYOD made it convenient to capture photos for record and to search for more information online.*

While Group member 1 demonstrated deeper knowledge construction from the inquiry, he also indicated his preference for using apps on his device in the exploratory process. Other student members also reflected their unique experience in the collective learning process. For example, Group member 2 reported:

> *I discover a unique scent of faba beans while I study the structure of it. Using BYOD to learn about this topic is very interesting because it involves teamwork and the use of photographs to record the experiment process. I am looking forward to participating in activities of this sort.*

In addition, the group expressed their positive attitude towards learning with their own device. When they were asked about the opinions of the BYOD project, all students held a positive attitude. Group member 2 responded, ‘We used Evernote and Skitch when carrying out experiments. They reinforce our learning as we use them for revisions before exams and after lessons.’ This suggests that the Evernote and Skitch apps helped students to document their learning process which was useful for their course review. They also appeared to develop a sense of ownership associated with knowledge construction during the inquiry, through using the apps on BYOD.

4. Experienced challenges

We encountered a few challenges in this study. First, the problems of misalignments existed between the teacher’s beliefs of inquiry-based learning and his pedagogical practices. The teacher advocated inquiry-based learning approach and use of BYOD to supported authentic learning tasks, and the teacher and the researcher co-designed the lessons using the approach. However, the actual enactment of the pedagogical activities was still technological driven. Secondly, because inquiry learning process spanned over multiple spaces, how to capture learners' learning experience and evaluate their learning was a big challenge. Thirdly, the majority of primary students were not skillful in inputting a long text in making reflections. Fourthly, some students did not have a mobile device. How to solve the problem to avoid digital divide was another challenge encountered. Finally, students might come across technical problems and learning difficulties, especially problems coming across beyond the campus.

5. Main strategies

To cope with the challenges mentioned about, we adopted the following strategies:

First, regarding the misalignment between the teacher beliefs and practices, the researcher had reciprocal interactions and discussed and designed the lessons together with the teacher. In addition, the researcher provided a five social constructivist principles (Kong & Song, 2014) with exemplars for the teacher to understand that this approach, different from the conventional one emphasizing "best practices" with prescribed procedures, provides more flexible scaffoldings under guiding principles. The research made an attempt to build up teachers' capacity for promoting inquiry-based learning in a way that is aligned with learners' process of practicing inquiry-based learning. The five core instructional principles were adapted from a set of principles for progressive inquiry (Scardamalia, 2002), namely, working on real problems, encouraging diverse ideas, providing collaborative opportunities, using authoritative sources constructively; and doing formative assessment (Kong & Song, 2014).

Secondly, to capture learners' inquiry process across multiple settings, we focused on designing learning tasks that encouraged students to create artifacts in multiple modalities of text, picture and audio files using Skitch, camera and recording apps, and used social network platform Edmodo to allow students to post their artifacts there. In addition, to document individual learner's learning progress, they were asked to make reflections on Evernote after each topic of study which could be shared on Edmodo according to their own preference.

Thirdly, while students made reflections on Evernote, the teacher allowed students to make audio files about what they learned instead of typing long text. Fourthly, the school provided devices to students who did not have a mobile device. In the meantime, they were allocated into different groups to balance the distribution of the devices.

Finally, in order to help solve students' learning difficulties and technical problems anytime, anywhere, the teacher allowed students to post questions to Edmodo so that the other students or the teacher could respond to those issues within their reach.

6. Conclusions

In this study, the students adopted different apps to help complete the science learning tasks at their own paces and across different spaces which helped to foster personalized learning and increase independent learning capacities. This is a shift from 'fixed content and fixed timing' of a traditional lesson to 'flexible content and flexible timing' of a mobilized lesson (Looi et al., 2009). In addition, adopting BYOD, students could enjoy the convenience and intimacy with their own mobile devices; and the flexible learning activities tailored for their own needs contributed to a sense of ownership of their own learning. Moreover, in this study, inquiry-based pedagogy in tandem with various apps and BYOD technological model could help improve students' learning engagement and knowledge attainment in science. Future studies may focus on investigating how to capture students' seamless science inquiry process and evaluate their learning in authentic contexts more holistically, and how to help the teacher to orchestrate the seamless learning more effectively.

References

Alberta Education. (2012). *Bring your own device: A guide for schools*. Retrieved from http://www.castledome.yuma.org/filestore/YumaEl_BYODGuide_072413.pdf

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15–42.

Falloon, G. (2015). What's the difference? Learning collaboratively using iPads in conventional classrooms. *Computers & Education*, *84*, 62–77.

Hakkarainen, K. (2003). Progressive inquiry in a computer-supported biology class. *Journal of Research in Science Teaching*, *40*(10), 1072–1088.

Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology*, *20*: 14406.

Kong, S. C., & Song, Y. (2014). The impact of a principle-based pedagogical design on inquiry-based learning in a seamless learning environment in Hong Kong. *Educational Technology & Society*, *17*(2), 127–141.

Lai, K. W., Khaddage, F., & Knezek, G. (2013). Blending student technology experiences in formal and informal learning. *Journal of Computer Assisted Learning*, *29*(5), 414–425.

Looi, C.-K., Wong, L.-H., So, H.-J., Seow, P., Toh, Y., Chen, W., Zhang, B., Norris, C., & Soloway, E. (2009). Anatomy of a mobilized lesson: Learning my way. *Computers & Education*, *53*(4), 1120–1132.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago: Open Court.

Song, Y. (2014). "Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school. *Computers & Education*, *74*, 50–60.

Song, Y. (2016). "We found the 'black spots' on campus on our own": Development of inquiry skills in primary science learning with BYOD (Bring Your Own Device). *Interactive Learning Environments*, *24*, 291–305.

Stahl, G. (2002). Rediscovering CSCL. In T. Koschmann, R. Hall, & N. Miyake (Eds.), *CSCL 2: Carrying forward the conversation* (pp. 169-181). Hillsdale, NJ: Lawrence Erlbaum.

Wong, L.-H., & Looi, C.-K. (2011). What seams do we remove in mobile-assisted seamless learning? A critical review of the literature. *Computers & Education*, *57*, 2364–2381.

Exploratory question posing: Towards improving students' knowledge integration performance

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Abstract: When students encounter new knowledge it is fragmented and fragile, not well connected to their existing knowledge. It is highly desirable that students integrate the knowledge pieces effectively. Traditional teaching–learning does not explicitly target improvement of students' knowledge integration. This paper shows the results of the first two cycles of an ongoing design-based research project that aims at devising a technology enhanced learning environment (TELE) to improve students' knowledge integration performance. The TELE is based on exploratory question posing activities, which involves the asking of new questions around a given concept. We anticipate that by the end of this design-based research we would be able to contribute with an effective online intervention to improve students' knowledge integration performance. Further we will analyze what are the mechanisms which lead to this improvement. The research is being carried out in data structures domain and the target population is engineering undergraduates.

Keywords: Question posing; Knowledge integration; Performance

1. Introduction

Knowledge integration (KI) is defined as the process by which learners sort out connections between new and existing ideas to reach more normative and coherent understanding in science (Liu, Lee, Hofstetter, & Linn, 2008). It is the ability to use theory or evidence to create a linked and coherent argument (Baxter & Glaser, 1998; Nichols & Sugrue, 1999; Shepard, 2000). Due to this emphasis on the coherence across science ideas KI leads to deep understanding in science (Linn, 2006). The process of making links and forming arguments results in a more organized understanding of the concepts (Lee, Liu, & Linn, 2011). It follows the constructivist view of learning and is based on extensive research on science instruction (Linn, 2006; Linn, Davis, & Bell, 2004). According to the connectionist theory of cognition (Fodor & Pylyshyn, 1988), if a concept is represented in the brain by a complex network including connections to multiple contexts and modalities, the learner has an opportunity to access, manipulate and use the concept in several ways in problem solving and inquiry. However for these connections to form a coherent representation, KI is required.

To the best of our knowledge traditional teaching–learning strategies do not explicitly target improvement of students' KI. This paper shows the results of the first two cycles of an ongoing design-based research that aims at designing a technology enhanced learning environment (TELE) to improve students' KI performance. The TELE is based on exploratory question posing (QP) activities, which involve the asking of new questions around a given concept. In addition to designing the TELE the overall research goal of the DBR is also to investigate what are the mechanisms which lead to the improvement of KI. Fig. 1 shows the overview of DBR cycles.

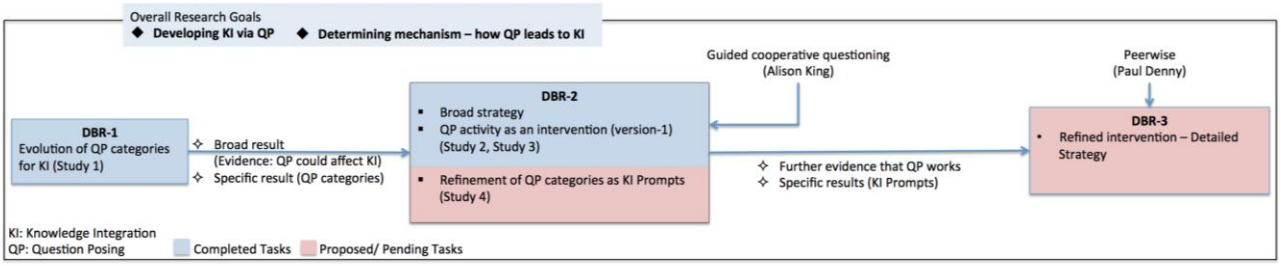


Fig. 1. Overview of DBR cycles

From cognitive science perspective it appears that questions are the 'indicators' of exploration. The integration of concepts is caused by (if anything) the exploration process, which comes before and after the questioning. Studies done by King and Rosenshine (1993) also suggest that questioning can promote connections between the concepts. With this background we investigated how does questioning activity provides affordance for knowledge integration. This lead to the first cycle of our design based research (DBR), which we would be discussing in the subsequent section. In the second DBR cycle it we have got qualitative evidence that questioning affects the deep learning and knowledge integration. To quote a few students' feedbacks on how did the questioning activity affected their learning:

(i) "Learning 'how to question' would help in understanding the concepts better."

(ii) "We can think about a topic in different ways and therefore can learn more concepts at the same time."

(iii) "It made us to explore more into the topics and making better questions of each things..."

(iv) "It made us to learn the thinking process... given a concept, how to deeply look into it…".

(v) "Workshop [activity] helped in given any data, video, lecture, how to assimilate it and extract important things out of it."

2. Design based research (DBR)

As shown in Fig. 1, studies in the first DBR cycle (DBR-1) provided broad evidence that QP is the indicator of KI and can affect KI. Another important outcome of the DBR-1 is the questioning categories, which were used as the question prompts in the first version of the intervention. In the second DBR cycle (DBR-2) we designed an intervention where QP activities were based on the guided cooperative question model proposed by King and Rosenshine (1993), which used the questioning categories as question prompts. The

DBR-2 contained a total of 3 studies – first one was to test the effectiveness of the QP intervention; the second was to qualitatively investigate how QP was helpful to KI, as perceived by the students and the third was to refine the QP categories by analyzing a larger question-corpus. This analysis is under progress and will lead to the final KI-prompts, which will be used in the next version of the intervention. The results of the first two studies are presented in the subsequent section. In the third DBR cycle (DBR-3) we propose to design and test the next version of the intervention. It will use the KI-prompts obtained from the study-4 of DBR-2, and we use some ideas from the activity of question sharing and discussion as proposed in PeerWise (Denny, Luxton-Reilly, & Hamer, 2008). In the subsequent sub-sections we describe the work done in DBR-1 and DBR-2.

2.1. DBR cycle 1

The research objective of the first DBR cycle was to investigate how question posing affords KI. We conducted three QP sessions: two in a data structures (DS) course and one in an artificial intelligence (AI) course and collected a corpus of 104 student-posed questions. We performed first set of inductive qualitative analysis of this corpus to find out that there are two types of knowledge (or concepts) present in any question: (i) The knowledge delivered explicitly in the video lecture. We call it "given" knowledge, and (ii) The knowledge not delivered explicitly in the video lecture. We call it "prior" knowledge. There were few questions, which aimed at explicit reiteration of the content of the video lecture and did not have any prior knowledge. We call them clarification questions (Mishra & Iyer, 2015). All other questions, which lead to unfolding of a new concept, are called exploratory questions. We also found that every exploratory question exhibited certain association between the prior and the given knowledge. With this information we performed a second set of inductive qualitative analysis of the same corpus to answer our research question: “How do students integrate prior knowledge and given knowledge to arrive at a question during question posing?” Open coding and axial coding (Strauss & Corbin, 1990) were carried out separately for each of the question sets (DS and AI questions). This helped in testing if the results of the axial coding are valid across the Computer Applications domains (DS and AI). This qualitative study has been reported in detail in (Mishra & Iyer, 2015). At the end of the analysis there were seven evident strategies by which students integrate their prior knowledge and the given knowledge to come up with exploratory questions. These seven strategies are further grouped into three classes of the exploratory questioning: 1) *Employ*, where students integrate the concepts from given knowledge with some goal ‘application’ or ‘structural arrangement’. 2) *Associate*, where concepts from given and prior knowledge are integrated to seek insight about the given knowledge or prior knowledge. 3) *Operate*, where the QP involves integrating given knowledge with known goal state (or modifications) and seek operations/procedure to achieve the goal state. The examples of these three questioning classes, with “arrays” as a concept from the given knowledge (video lecture) respectively are: 1)"Can I create social network graph using array?” (Employ); 2) ”How bad is array than the structures when it comes to using less memory?” (Associate); “How can I search a value from the list of values stored as an array?” (Operate). This has given us evidence that the exploratory QP process involves the knowledge integration process.

2.2. DBR cycle 2

In the second DBR cycle we aimed at investigating the research question: “What is the effect of questioning activity on students’ KI. Fig. 2 shows the learning-strategy (and the research design) of the study-2. The study was conducted with 24 first year computer science-engineering undergrads. There were 12 students each in control and experimental groups. In the start students were given a 1 min and 26 sec long video on how to make a simple concept map (CMap). This was important because assessment is completely concept mapping based and students had no prior exposure to either to CMAP tool or to CMaps. The “Watch” activity was about watching a 17 minutes long video lecture on “Linked List”. Students were allowed to seek the video back and forth and watch the video as many times as they want, within the stipulated maximum time. In the *phases 2, 3 and 4* students read slides on different questioning types (clarification and exploratory) and different questioning prompts, they posed questions around the content of the video and they shared and face-to-face discussed their questions. There was no specific script and control to what students were discussing. The control group got double time to watch the same video lecture. In the posttest students were given parking lot of the keywords from the video lecture they watched and were told to create CMaps to reflect what they learnt in the “linked list” video. The CMaps submitted in the posttest were used to assess KI performances of the students. The rubric proposed by Liu et al. (2008) for assessing the knowledge integration construct was adapted for evaluating CMaps. The four ordered levels of KI performances given by Liu et al. (2008), viz., Score 0 for “No Link”, Score 1 for “Partial Link”, Score 2 for “Full Link”, Score 3 for “Complex Link” were mapped to the four criteria in a CMap. Following criteria were evaluated in any CMap: (1) count of triplets, (2) count of valid triplets (partial link), (3) count of partial links having extension by at least one node (full links), (4) count of full links having extension by more than one node (complex links). Here one triplet refers to a pair of two concepts connected with one link. The comparison of the two groups on each criteria of the rubric is shown in Fig. 3. Though it wasn’t statistically significant, the result gives a trend that the questioning group scored higher than the control group. The qualitative feedback collected in the study-3 gives an account of the students’ perceptions that the questioning activity helped them in: *“deep thinking”*, *“relating the concepts to prior knowledge”* and *“self-examining understanding.”*

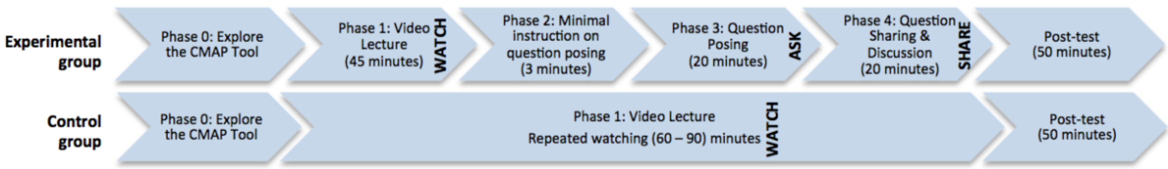
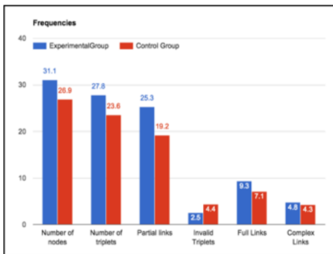


Fig. 2. Activities in the study-2 of DBR-2



	Nodes	Triplets	Valid triplets	Invalid triplets	Full links	Complex links
Mann-Whitney U	50.50	42.00	40.00	41.50	61.50	72.00
Wilcoxon W	128.50	120.00	118.00	119.50	139.50	150.00
Z	-1.24	-1.74	-1.85	-1.79	-.61	.00
P (2-tailed)	.213	.082	.064	.073	.541	1.000

Test Statistics, $N^{experimental} = N^{Control} = 12$

Fig. 3. Result from the Study-2

3. Experienced challenges and main strategies

One of the major challenges at the start of this DBR project was that we didn't have any theoretical insights regarding how student's questioning can be tailored to suit knowledge integration/ deep learning. We performed inductive qualitative research with a very broad research question, "what do students do while posing questions as evident from the question artifacts generated by them?" This exploratory qualitative research gave us the insight that students attempt to integrate their prior knowledge with the given knowledge. After this confirming evidence we moved ahead and repeated the data analysis with a more specific research question, "What are the different patterns in which students integrate knowledge pieces while generating questions?"

Another challenge in this project is about capturing what exactly goes on inside the minds of students while generating questions. This is important because we have to identify the mechanisms that lead to students' improvement of knowledge integration. For this we use the artifacts generated by the students, which includes generated questions, and discussion logs along with student interviews and perception surveys. Given a non-trivial construct of knowledge integration, the challenge is to structure interviews and surveys such that they can elicit the mechanisms of knowledge integration without biasing or complicating the reflection process of the students. We need to delimit our claims to the kind of inferences that our collected data affords.

In some of the pilots we found that when the intervention is too long then students' engagement with activities fade with time. For example, in one of the pilots we wanted to administer the perception survey and interview on the day of the intervention. The intervention plus a posttest requires 2 hours of students' engagement and a pretest would add 30 more minutes. In this situation when we asked students for their qualitative feedback we found that students were reluctant to give deep responses. After this experience we decided to split the data collection into two separate studies. This is the reason why we did separate studies (in the DBR-cycle-2) for collecting students' feedback about the effect of the questioning process on their learning. In the DBR-cycle-3 we propose to conduct smaller pilots to do qualitative studies of our final strategy and a big quantitative study to measure the effectiveness of the strategy. The follow-up challenge in this methodology is to ensure that the split studies are done with equivalent samples. Moreover, the challenge of ensuring cohort equivalence is even more prominent as cohort changes are inevitable across the DBR cycles because the DBR cycles take longer to implement, usually multiple years.

Another set of challenges are concerned with the domain expertise of the researcher. The inductive qualitative research could have not been possible if the researchers (data analysts) did not have domain knowledge of computer science. In fact for checking for reliability the co-analysts should also have domain knowledge. So to establish the generalizability of the knowledge integration prompts we propose to partner with domain experts outside computer science domain. By the end of this DBR project we intend to test (if not ensure) that the evolved knowledge integration prompts are generalizable to other CS topics and to other domains. To achieve this we will repeat similar QP exercises with the students of other domains and validate if the KI prompts are applicable to the QP in other domains.

One of our goals is to situate KI in an authentic inquiry task. It is difficult to ensure that students have authentic engagement with the activities. In the DBR-cycle-2 for example, we found that not all students actually use the prompts to do the questioning activity. The possible strategies to address this challenge are: (i) structure the activities such that it becomes inevitable for the students to engage with the prompts; (ii) provide students motivation, such as scores/points. In the DBR-cycle-3 we are working more on structuring the activities.

4. Conclusion

In this paper we have reported design, implementation, results and associated challenges of an ongoing design-based research project. By the end of this DBR project we aim at developing a TELE to improve students knowledge integration performance. The TELE shall provide a synchronous online learning environment wherein students shall do QP and reflection activities based on meta-cognitive KI-prompts. The completed studies have been implemented in semi-online mode. Total 4 studies have already been done, and data from 3 studies have been analyzed. The results till the current progress of the DBR shows that question posing is not just an indicator of KI but has potential to improve KI performance.

References

Baxter, G. P., & Glaser, R. (1998). Investigating the cognitive complexity of science assessments. *Educational Measurement: Issues and Practice, 17*(3), 37–45.

Denny, P., Luxton-Reilly, A., & Hamer, J. (2008). Student use of the PeerWise system. *ACM SIGCSE Bulletin, 40*(3), 73–77.

Fodor, J. A., & Pylyshyn, Z. W. (1988). Connectionism and cognitive architecture: A critical analysis. *Cognition, 28*(1), 3–71.

King, A., & Rosenshine, B. (1993). Effects of guided cooperative questioning on children's knowledge construction. *The Journal of Experimental Education, 61*(2), 127–148.

Lee, H. S., Liu, O. L., & Linn, M. C. (2011). Validating measurement of knowledge integration in science using multiple-choice and explanation items. *Applied Measurement in Education, 24*(2), 115–136.

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 243–264). New York: Cambridge Univ. Press.

Linn, M. C., Davis, E. A., & Bell, P. (Eds.). (2004). *Internet environments for science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Liu, O. L., Lee, H. S., Hofstetter, C., & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures, and evidence. *Educational Assessment, 13*(1), 33–55.

Mishra, S., & Iyer, S. (2015, June). Question-posing strategies used by students for exploring data structures. In *Proceedings of the ACM Conference on Innovation and Technology in Computer Science Education* (pp. 171–176). ACM.

Nichols, P., & Sugrue, B. (1999). The lack of fidelity between cognitively complex constructs and conventional test development practice. *Educational Measurement: Issues and Practice*, *18*(2), 18–29.

Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher, 29*(7), 4–14.

Analyzing instant messaging environment as a learning-teaching tool

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Abstract: Instant messaging environments (like Whatsapp, Telegram and Chat activity in OLPC) are popular among children. Simple rule-based games are often played and enjoyed in these environments. Considering these engaging aspects, we built a similar learning environment in our study, to make arithmetic learning fun. This paper shows results of two cycles of ongoing design-based research, using simple rule-based educational games built in instant messaging environment. Fifteen tribal school students (from 3rd and 4th grade) participated in the first cycle, and 21 urban school students (4th grade) participated in the second cycle. At the end of the second cycle, we found that children enjoyed playing games and their arithmetic skills improved significantly ($p = 0.0068$). This paper also discusses the challenges faced by the researcher during the study, and the strategies designed to tackle these challenges.

Keywords: Analyzing; Messaging; Learning-teaching tool

1. Introduction

Games are often used as an educational tool, because they make the learning process a fun activity (Kirriemuir & McFarlane, 2004). Yet games go farther than that, it has been reported that educational games affect four motivational components: attention, relevance, confidence, and satisfaction (Klein & Freitag, 1991). Positive effects of games on motivation are gender neutral (Klein & Freitag, 1991). Games provide an interesting context for situating educational concepts. Learning in the context of solving complex problems not only helps the learner in retaining more information, the learner also tends to perform better at solving problems (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990). Advent of computers in classroom has created new possibilities, such as multi-user educational games, and effective communication between students and teachers.

In traditional classroom there are limitations to inter-student and student-teacher communication. If all of them speak together it creates chaos. But this problem can be solved with networked computers. Student can communicate effectively with each other and the teacher, using text-based messaging environments.

We observed that chatting environments (like Whatsapp, Telelgram, and Chat activity in One-Laptop-Per-Child (OLPC[1])) are very popular among students. Hence, we created an arithmetic learning game, based on the chat environment. In the following section, we describe in brief a study, where we tested this.

1.1. DBR cycle-0 (Pilot)

The pilot study was conducted with 15 students from 3rd and 4th grade (age group 8-12 years), who belonged to a primary school in a tribal village in India. The students played Chat game on XO[2] laptops given by the OLPC Foundation for an intervention period of six months.

Semi-structured personal interviews were conducted to check the understanding of students both before and after the intervention. Data analysis showed that after intervention, along with improvement in arithmetic skill's, students designed different strategies to solve the addition and subtraction problems with more accuracy and speed. They also learned to use multiplication as a special case of addition, and enjoyed the number games in chat environment (Shaikh, Nagarjuna, & Chandrasekharan, 2013).

The chat game used in our pilot study had some limitations, for example, there were no features for evaluation of performance in the game, and no record of game transaction was maintained. To overcome these limitations, we decided to convert the chat application into a full-fledged number game by adding some features. In this paper, we report the process of development and testing of this chat-based number game, ChatStudio.

1.2. DBR cycle-1

Context and participants

This study was conducted in a suburban school in Mumbai. It is a semi-government school, where the medium of instruction is vernacular (Marathi). A single teacher teaches all the subjects to this grade. The researcher acted as a part-time teacher during the course of the study. 21 students from grade 4 (age group 9-11 years) participated in the study. The group consisted of 15 boys and 6 girls.

Study design

We followed design-based research (DBR) methodology for our research project. We chose DBR because it provides the flexibility of changing application design during the course of the study, it is especially important in studies where one is exploring possibilities for creating novel learning and teaching environments (Sutherland, 2004; Barab & Squire, 2004; The Design-Based Research Collective, 2003).

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1 "One Laptop per Child." 2009. 7 Apr. 2016 <http://one.laptop.org/>

2 "XO laptop - One Laptop per Child." 2007. 7 Apr. 2016 <http://laptop.org/laptop/>

Fig. 1 depicts the study design we followed. Our initial design was based on the insights from DBR cycle-0 (pilot study), which we improved over the course of the study through repeated cycles of trials in the classroom and development in the lab. Fig. 2 shows an example of a number game. There were around 40 classroom sessions (each session = 45 minutes) where students played the number games.

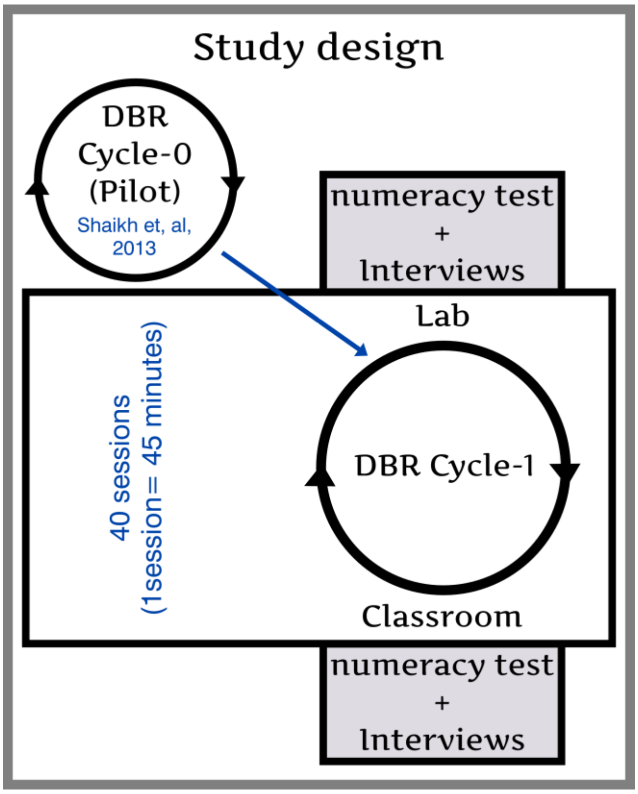

Fig. 1. Study design

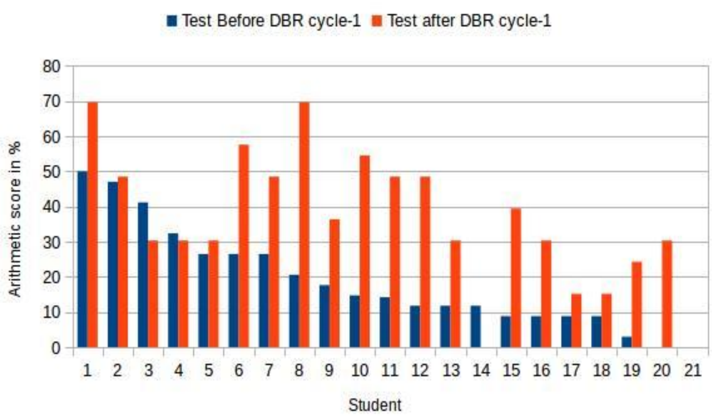

Fig. 3. Results from DBR cycle-1

1.3. Results from DBR cycle-1

During DBR cycle-1, we collected process data including computer logs, audio recordings of each session, audio recordings of interviews, and field notes. We also collected test scores of students on arithmetic proficiency tests, at the beginning and the end of DBR cycle-1. We are in the process of analyzing the process data and have very preliminary results to report at this point of time. Students' performance in two arithmetic proficiency tests showed that students' arithmetic skills have improved significantly (p= 0.0068). Fig. 3 shows results from DBR cycle-1.

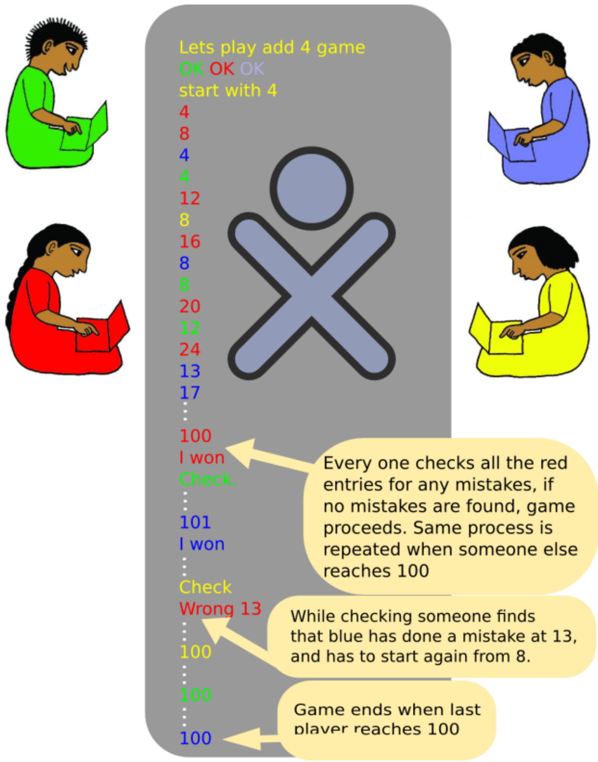

Fig. 2. An example of a number game (Shaikh et al., 2013).
(*All four students discuss and decide to play 'add 4' game. The game starts. Everyone starts adding 4 to the starting number (here zero) repeatedly. Red declares she won, as she reached first three digit number in the series. Everyone stops for a while and check if Red did any mistake. No mistake found. Game continues. Now Blue declares he won. Everyone checks if he made any mistakes, Red finds that Blue wrote 13 instead of 12. Blue has to go one step back and start addition from 8 again. Game continues, this cycle repeats till everyone reaches three digit number in that series*)

2. Challenges faced and strategies designed

In DBR cycle-0 we observed that the number game in Chat activity was very popular among students and it helped in their learning. Students played the game, and they enjoyed it. But there was no feature in the game to see their progress over time. We realized the importance of adding new features to the game, so that students and their teacher could monitor the progress over time. With this aim, we started DBR cycle-1. The biggest challenge we faced during DBR cycle-1 was to make sure that while adding extra features to the game, we do not lose the enjoyment aspect of the game. According to our previous analysis, we realized that the fun was due to speed, visibility, and engagement (Shaikh, Nagarjuna, & Chandrasekharan, 2013). At the same time, the game was designed based on educational principles, and we aimed to make the game environment conducive for learning and to find proper indicators to assess the learning. Throughout the DBR cycle-1, we tried to balance these two aspects of fun and evaluation of learning in the game.

For example, we added a feature to the game to evaluate each student's performance in a game session. We observed that all the students didn't finish their game simultaneously, so if we used the evaluation button early, then some students would be left behind; and if we waited till everyone finished, then other students would get bored. To tackle this problem, we decided to have many evaluation cycles instead of one. Thus, to keep the students engaged, especially the ones who finished early, we added one more rule to the game, that they can check others' answers on their computer screen, and they earn points if they identify the mistakes made by other students. It solved the problem of faster students getting bored because they had nothing to do, and slower students got more time to finish their game.

Another feature let student choose roles: either participant or mentor. Initially, we wanted the possibility of any student becoming a mentor at any point in the game. But in the field trials, we observed that there were too many issues with this mode; students got confused, and the application was not able to handle more than one mentor. To address this issue, we decided to have two different versions of the application, one for the mentor and another for the participant. It solved the problem but we ended up losing the fun element. Now any student couldn't just go and choose to be a mentor; instead s/he had to request the mentor to play a game which s/he wanted. And most of the time the teacher was the mentor.

Guidelines by Kirriemuir and McFarlane (2004), based on their review work, helped us immensely. We used them as a framework to evaluate every change/addition in our game. The guidelines are as follows:

1. A task that player can complete
2. Focusing on the task
3. A task with clear goals
4. Immediate feedback
5. Deep but effortless involvement
6. Exercising a sense of control over ones action

As school students and the teacher were participants in our study and we used to go to school to test our application, we faced lots of problems. School had a life of its own. Many programs were going on simultaneously. We would add some feature to the game, and wanted to test it with the students. But students would be busy, or not in a mood to participate in our activities when they were tired, sad, or excited due to another preceding activity. Due to these issues, the testing got delayed, it further delayed the application development, and as a result we ended up extending our study. We could not work out a way around these problems.

3. Conclusion

In this paper, we have reported various aspects (design, implementation, results, challenges faced and strategies designed to tackle these) of an ongoing design-based research project. Our results from both the cycles show that instant messaging environment has the potential of becoming a fun-filled learning-teaching tool. Detailed analysis of data collected during the study (computer logs, audio recordings, interviews, and field notes) is in progress. At the end of analysis, we expect to find out what actually happens in ChatStudio, and what features of the design helped in learning.

References

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1–14.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Cognition, Education and Multimedia: Exploring ideas in high technolog*y (pp. 163–205), Hillsdale, NJ: Erlbaum.

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*, 5–8.

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning.* Retrieved from http://telearn.archives-ouvertes.fr/hal-00190453/

Klein, J. D., & Freitag, E. (1991). Effects of using an instructional game on motivation and performance. *The Journal of Educational Research, 84*(5), 303–308.

Shaikh, R., Nagarjuna, G., & Chandrasekharan, S. (2013). Socialising mathematics: Collaborative, constructive and distributed learning of arithmetic using a chat application. In *Proceedings of epiSTEME – 5* (pp. 321 – 327). Mumbai, India.

Sutherland, R. (2004). Designs for learning: ICT and knowledge in the classroom. *Computers & Education, 43*(1), 5–16.