IDM-SUPPORTED AND WEB-BASED VIDEO CASES TO DEVELOP PROFESSIONAL LEARNING COMMUNITIES FOR TEACHERS IN MATHEMATICS PROBLEM SOLVING IN SINGAPORE

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Paper presented at the 4th Redesigning Pedagogy International Conference

May/June 2011, Singapore

Abstract

Situated learning perspective and the principal of authenticity has guided design of the video cases which were derived from authentic problems of a classroom teacher and his unit of lessons (see more detail in the abstract of the second paper). Informed by literature on mathematics problem solving (such as Stacey & MacGregor, 1999) and the model method (such as Ng & Lee, 2009), three video cases were developed to highlight the following pedagogical themes: 1) understanding the case teacher's rationale and approaches to bridging; 2) understanding the cognitive challenges in bridging; and 3) understanding students' feedback and initial Algebra learning outcome. Interviews with the case teacher provided a first-person narration of his rationale for planning, teaching and assessing student learning. To support teachers' viewing and reflection, scaffolds (prompts) were designed in the form of viewing questions to stimulate critical analysis of a case lesson on the content, instructional goals and facilitation of student understanding. In the mean time, we anchored teacher learning in the Macrocontexts of video-based problem solving for repeated viewing and responses to questions in the personal blogs called, My Workplace, which is merged together with an online Discussion Forum to generate multiple perspectives (Cognition & Technology Group at Vanderbilt, 1993). Our Microcontext includes identifying 'critical incidents' according to what they think as important, difficult, and hinge points in a case lesson (Paine, Fang & Wilson, 2003) and discussion supported by e-facilitation in the Forum platform (Wang, 2008). Building of the Online PLC was piloted in the case teacher's school for almost a year (Feb – Nov 2010), which started from a group of mathematics teacher leaders and later extended to 70 English-medium teachers of the school (see more detail in the abstract of the third paper). The teachers' feedback in piloting stage has informed several rounds of iterative design and continuous improvements of the design and use (Stephens & Hartman, 2004). Research is going on to draw out implications for scaling up the use in diverse school contexts and learning platforms (such as lesson study)

Background

In recent years, professional learning communities (PLCs) involving educators at all levels of the educational continuum are increasingly considered an effective means to promoting deep and sustained teacher development (Borko et al, 2009). In September 2009, Ministry of Education of Singapore (MOE) called for schools to build PLCs to create "continuous professional dialogue and feedback" for enhanced classroom practice and innovation. This movement comes at a time to address the lack of teacher collaboration in observing, critiquing and improving lessons in the local schools, which is in contrast to the long traditions of collaborative school cultures in building teacher knowledge of practice in China and Japan (Fang et al, 2009).

How to help students transition from concrete arithmetic to abstract algebra learning has been a meaningful problem facing mathematics education worldwide. In the local context of Singapore, the Ministry of Education (MOE) recommends a dozen of heuristics as a rule of thumb for students to solve mathematical problems. Among them, 'draw a diagram' is widely used in the classroom teaching of primary schools through a technique called "the model method" (drawing rectangular diagrams to visually represent quantitative information in a given word problem). On the one hand, model method offers a powerful and potential tool for primary school children to bridge the gap between arithmetic and algebraic thinking and is believed to have enabled many Singaporean primary school children to solve mathematically very challenging problems (Beckmann, 2004; Ng et al, 2006). On the other hand, however, many lower secondary teachers view it as hindrance to learning symbolic algebra and thus discourage students from using it (Ng et al, 2006). In fact, researchers are concerned that by emphasizing concrete arithmetic thinking through the habit of using the model method throughout primary school years, students' transitioning to abstract algebraic thinking could be interfered (Looi & Lim, 2009; Stacey & MacGregor, 2000).

In our research, we situated the design of video cases in the local context characterized by the need to address the central issues of bridging from arithmetic to algebra learning through the model method. We aimed to promote a "professional dialogue" in online PLCs around these issues by engaging teachers in analyzing and reasoning with the video cases of teaching on bridging developed from one teacher's unit of 8 lessons in his Primary 6 classroom. Through sharing and discussion, it is hoped that teachers would gain a deeper understanding of the issues of bridging and be able to develop the knowledge and skills to address them to enhance student learning.

Most studies tended to focus on the use and implementation of video cases or instead of designing their own, they used and studied video cases developed by others (Seago et al, 2004). Meanwhile, successful multimedia cases, built with support and scaffolds, have been increasingly reported in recent years (Boaler & Humphreys, 2005; Van Es & Sherin, 2002) but little is known in regard with how to use them in online discussion and community building, much less about how to sustain one. These questions remain to be explored to help us understand how to build mathematics teachers' knowledge and in what ways can online technologies promote their knowledge.

The eventual goal of this design-based intervention is to broaden the access of teachers to online collegial interactive platforms and opportunity to analyze classroom discourse, teacher decision making, tools of teaching and student learning in regular lessons. Whether teachers are able to benefit fruitfully from such online resources depends mostly on the quality of the design, and it is such quality of design that will eventually determine whether the use of the resources and learning opportunities are made accessible to teachers through the Internet. To achieve the goal, we focused on addressing the following research questions:

1) What constitutes and how to develop a rich and educative video case on problem solving (bridging algebra through the model method) facilitated by interactive digital media and web technology?

2) What constitutes and how to design an effective online platform for teacher learning anchored the video cases of teaching surrounding the bridging issues in Singapore?
3) What have we achieved in piloting the design in one local school to build an online PLC?

Literature Review

With the above context in view, our research aimed to develop an online PLC to co-construct web-based IDM-supported cognitive tools, focusing on digital video cases in an effort to enhance the learning of pre-service teachers and professional development of in-service teachers in mathematical problem solving. We aim at engaging them in reflecting on and reasoning about classroom practices by probing into the underpinning pedagogical rationales and decision-making actions *in-situ*. In the meantime, contribute to widening the repertoire of teaching strategies for developing students' problem solving capacity and enable them to understand students' thinking and reasoning during their problem solving interactions with peers. Teachers' participation in the online PLC and engagement with the cases are shared through discussion forums. In so doing, teachers participate as both consumers and builders in knowledge construction. The research dimension aims to find out what constitutes and how to develop a rich and educative video case facilitated by interactive IDM and web technology and how to scale it up and sustain the effort by strengthening such a PLC.

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The Local Problem Context

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context of Singapore, the Ministry of Education (MOE) recommends a dozen of heuristics as a rule of thumb for students to solve mathematical problems. Among them, 'draw a diagram' is widely used in the classroom teaching of primary schools through a technique called "the model method" (drawing rectangular diagrams to visually represent quantitative information in a given word problem). On the one hand, model method offers a powerful and potential tool for primary school children to bridge the gap between arithmetic and algebraic thinking and is believed to have enabled many Singaporean primary school children to solve mathematically very challenging problems (Beckmann, 2004; Ng, 2006). On the other hand, however, many lower secondary teachers view it as hindrance to learning symbolic algebra and thus discourage students from using it (Ng et al, 2006). In fact, researchers are concerned that by emphasizing concrete arithmetic thinking through the habit of using the model method throughout primary school years, students' transitioning to abstract algebraic thinking could be interfered (Looi & Lim, 2009; Stacey & MacGregor, 2000).

In our project, we situated the design in the local context characterized by the need as well as attempt to address the central issues of bridging from arithmetic to algebra learning through the model method. We aimed to promote a "professional dialogue" in online PLCs around these issues by engaging teachers in analyzing and reasoning with the videotaped teaching on bridging. Through sharing and discussion, it is hoped that teachers would gain a deeper understanding of the issues of bridging and be able to develop the knowledge and skills to address them to enhance student learning. With these purposes in view, we developed a set of web-based multimedia video cases by drawing on a unit of Primary 5 (5th Grade) lessons on fractions word problems as a resource (or tool) to trigger knowledge and community building in the online environment.

Literature Review and Conceptual Framework

In many countries, including Singapore, teaching long hours behind closed doors (Fang, Lee et al., in press; Lortie, 1975), teachers usually find it difficult to set aside time to observe and discuss other teachers' practices with colleagues or consulting teacher educators. Furthermore, the traditional one-short workshops with little, if any, follow-up support (which are still commonly used for teacher professional development in Singapore) are proven to be quite inadequate to enable transfer of learning to daily classroom practices (Little, 1993; Putnam & Borko, 2000). Therefore, this calls for forms of pedagogical resources that are easily accessible, rich, interactive, continuous, and yet have high flexibility of time and space for teachers and students to use. With this regard, web-based cognitive tools have potential to address this gap. In developing such resources, findings of what deemed effective problem-solving instructions in other countries are important. Yet, given the culturally embedded nature of teaching (Alexander, 2000; Stigler & Hiebert, 1998, 1999), it is urgent to tap into the instructional resources within the context of Singapore schools to meet the demands relevant to local problem-solving pedagogies.

As Lave and Wenger (1991) posited, "a community of practice is an intrinsic condition for the existence of knowledge (p. 98)" and such knowledge often resides in different communities outside schools, such as universities, research institutions,

policy makers and related external agencies. This brings us to conceiving the idea of constructing a *virtual* community of practice in the form of an online PLC overtime, in which the members from different communities participate by engaging with, what Shulman (1987) advocated, pedagogical reasoning and actions around the core of classroom interactions (Cohen, Raudenbush, & Ball, 2003) through the web-based cognitive tools, such as video cases, individual blogs and sharing in the online discussion forums. Co-constructing cognitive tools and pedagogical resources thus becomes shared tasks (Cobb, McClain, de Silva Lamberg, & Dean, 2003) for building *case-based knowledge* of mathematics problem-solving pedagogy. It is believed that well-developed video cases and forums are able to engage participation and knowledge building through distributed expertise (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004).

As mentioned earlier, Ball and Cohen (2000) characterized classroom teaching as featured by complex streams of conversations, actions, interactions among teachers, students, and the subject matter in milieu. Faced with dynamic and complex interactions and diverse learners and contents, a teacher needs to develop the knowledge and ability to adapt to changing situations (Spiro et al, 2003). Many believe that such knowledge is embedded in cases and can be learned by interpreting through the situation in which the case lies (Putnam and Borko, 2000; Shulman, 1992). In doing so, the learning is thus situated in the authentic context of teachers' daily work (Putnam and Borko, 2000). Learning through case-based reasoning can undergo application of known cases, interpretation and feedback, interpretation of results, modification of memory, which represent a trajectory of how professional knowledge develops (Kolodner, 1993). It also helps us to understand how experts reason and learn using their own experience and that of others.

From situated perspectives, learning happens as a result of "contributions of the individuals who participate, along with tools and artifacts" (Greeno et al, 1996, p. 20) in learning communities. Therefore, purposeful life-long professional learning for teachers should be characterized by ongoing deliberations on the dynamic tool-mediated interactions in teaching and the social construction of knowledge (Brown, Collins & Duguid, 1989). Video technology in the form of video cases can provide video clips of authentic representation of classroom situation; along with interviews with teachers, student work and assessment, they build resources for "high leverage practice" (Hatch & Grossman, 2009) for teachers at different stages of their careers. More recently, multimedia video technology and internet-based video streaming have become effective tools to "preserve the messiness and ambiguity of teachers' daily work" in visually effective cases (McGraw et al, 2007, p. 96). They are able to engage teachers in pedagogical reasoning (Schrader et al, 2003) and develop their eyes to "notice" what is important in teaching and in the course of those dynamic interactions (Van Es & Sherin, 2002).

As a general learning theory, situated learning perspective is able to provide us with the vision and principles for our design but it does not offer us any concrete design mechanism and tools that we needed for the actual design work. We gained inspiration from the notion of anchored instruction pioneered by the Cognition & Technology Group at Vanderbilt (1993). From a situated perspective, the Group anchored (or situated) their design and instruction in video-based problem solving

environments to help children "experience the value of experiencing the same setting from multiple perspectives" (p. 3). They called such learning environments, the *macrocontexts*, referring to the complex problem spaces in which children would be able to explore a problem "for an extended period of time from multiple perspectives" through "cooperative learning and teacher-directed mediation" (p. 3). Even though their design was mainly geared for children's use, the frames and elements were proven equally valuable in helping us design tools and environments for teacher learning.

In our own design, the *macrocontexts* refer specifically to the problem spaces created for teachers to collaboratively explore the complex issues around bridging for algebra learning. We anchored the learning in the form of video cases of authentic classroom teaching. Teachers analyzed the cases through repeated viewing via video streaming and took down their responses to viewing questions (serving as scaffolds, to be discussed later) in their blogs. The web forum created a public space for teachers to share their reflections and exchange views, for instance, around what they identified as 'critical incidents' in the teaching cases to open up diverse perspectives of a video case. To consolidate the anchor – the chosen case teacher and his practice represented in the cases, we used the case teacher's narration of his purposes, plans, and methods of bridging in building the "story structures" (p.4) of the cases. When the design was piloted in the case teacher's school, the case teacher himself also acted as a facilitator for the discussions to weave together and extend on the diverse views.

Methodology

1. Sampling

Our first set of video cases were designed based on the lessons of two Primary 5 teachers (Alex Tan and Chan Li Yin1) when they taught the Unit on Fractions in 2004 (Lioe, Fang, & Ho, 2008). Mr. Tan featured a teacher-centred approach and yet delivered high-level knowledge in teaching while Ms. Chan effectively used group work and student-led presentations in presenting their solutions. This unique mixture of East-Asian traditions of mathematics teaching and the teaching approach advocated by Western scholars could widen teachers' repertoire of teaching and open up conversations in community and knowledge building. Our second set of the video cases were developed from Mr. Tan's unit of 8 lessons on bridging algebra using the model methods in his Primary 6 classroom from Jan-Feb 2010 (see Appendix B for design details and screen shots of the video cases).

2. Major design elements

Most studies involving video technology do not include the design dimension. Researchers (including the author), who take on design as an integral part of their intervention and research, unanimously identified with the challenges in developing video cases, such as time and funding constraints, tedious editing processes, the need to develop storytelling and attend to the quality of the content (Fang et al,

[1] Teachers are all in pseudonyms.

2009a&b; Liedtka, 2001). The following major design elements were carefully put in place to engage teachers in analyzing teaching and trigger discussions.

a. Scaffolds

The role of a scaffold is to focus teachers' attention on the critical issues of a video case and develop the eye for noticing. Teachers need an effective scaffold to help them identify what is important in a teaching situation, make connections between specific classroom interactions and broader concepts and principles of teaching and learning (Van Es & Sherin, 2002) and reason about a given situation (Boaler & Humphreys, 2005). The scaffolds in our video cases include three levels of viewing questions: 1) describing the case teacher's approach to bridging; 2) make comment based on their own personal practical knowledge; and 3) reflect upon their own teaching practices if they are to teach the same topic.

b. Critical incidents

If the scaffolds and prompts were given by researchers based on their analysis, then the "critical incidents" were identified by teachers themselves as they indicate what and why they consider certain teaching and learning scenarios as critical in a video case. Two types of critical incidents were used: the general type on issues of education (Tripp, 1993) and the specific type focusing on the curriculum, teaching and learning on the "three points" commonly found in the mathematics curriculum materials and teachers' daily discourse in Shanghai (Fang et al, 2009; Paine, Fang & Wilson, 2003, p.51).

c. Authentic voice and teacher interviews

Interviews with the case teachers were conducted in October 2009 and Jan 2010 to gather the storyline from their perspectives, clarify their rationales and purposes behind the selected activities, and understand their embedded knowledge and beliefs. The case teachers also provided feedback on selection of the clips, and researchers' perspectives, and participated in designing the guiding questions of the video cases.

d. Role of facilitation

Increasingly, online facilitation is considered an important contributing factor in promoting online discussion and avoiding the weaknesses of asynchronous communication by providing feedback, encouraging participation and building depth in the discussions (Wang, 2008). The case teacher himself and the Math Committee teachers served as the e-facilitators to provide the social, managerial, and technical support as well as the intellectual support in the online community and knowledge building (White, 2004).

Findings

Piloting Stages

The piloting eventually was taken upon by the school and was made into a carefully designed blended model by the school. As shared by the school's project team chaired by the school's staff developer, the whole implementation was carefully thought out. "To start," as s members in the Mathematics Committee were selected

as the e-facilitators to lead the teachers in the same grade level. These facilitators were then invited to attend a sharing session offered by the case teacher who shared a video clip of his lesson and shared a few of his own viewing questions. Every member of the Mathematics committee was invited to share his or her thought on the questions and the case teacher played the role of the facilitator during the session to model a facilitator's role. After the face-to-face sharing, the Math Committee members had another session in which they watched the 2004 video cases in the school's AV room, respond to viewing questions which were later collated and commented on verbally during the second face-to-face session. The objective is to encourage teachers to probe deeper into the discussions, enriching it and go beyond generic and cursory responses."

In the second stage, when the 2010 video cases and online PLC website was ready, teachers were first shown the interface of the website and how to go about viewing the clips and adding in their comments. The other teachers were also encouraged to add their views to the comments made by other participants. The school identified general concerns for all English medium teachers and offered two face-face sessions on Seat Work and Classroom Culture facilitated by the case teacher. An e-facilitation session was then offered by the researchers to the Math Committee members to introduce them to good facilitation skills. Then all the English media teachers moved to online environment to view the first video case and respond to the viewing questions facilitated by the Math Committee members.

Such a step-by-step blended model has gradually familiarized the teachers with viewing and analyzing and commenting on videotaped lessons first through face-face hands-on experience and then moved to online environment. This gradual transition was less threatening and accepted by majority of the teachers. As seen in the findings below, majority of teachers found the online video cases and sharing useful and relevant to their needs. This year, the school looks into the possibility of going into the identification of critical incidents. Two sessions have so far been conducted and teachers were generally able to pick up their own critical incidents in the clips that they have viewed and they feel this is valuable to teachers' learning and reflection in general.

Findings from Piloting the Design to Build Online PLC in One Local School

1. Survey Results on the use of Video Cases and the E-learning Envionment

In August-September 2011, 70 teachers who participated in the school online PLC building were surveyed to learn about their experiences in using the video cases, personal blog and online discussion forums. All teachers completed the survey and due to some technicalities in google online survey, some responses were counted more than once, resulting a total response of 80 (n = 80). Due to difficulties in separating those double-counted responses, we treat all responses as single response.

The findings show that before the project teachers generally had little experience watching video cases of others' classrooms. 59 (72.75%) of them had never watched

any classroom videos prior to the programme, while 21 (26.25%) had some experience (referring to the Japanese lesson study videos). In general, this shows that multimedia video cases of authentic classroom practice is new to almost three quarters of the participants.

Regarding the relevance, usefulness, and user-friendliness of multimedia video cases to teachers' learning, most teachers rated them between average (36 – 48%) and good (43 – 49%). A small proportion of teachers rated very good for relevance and usefulness (10 – 11.25%). While a handful of them rated low (about 5 – 9%), none of the teachers rated very low. The details of the proportion can be found in the following table. This shows that the video case itself, serves as potential resource for teachers' learning while its user-friendliness needs to be further improved. (Table omitted)

Viewing/Guiding questions are important aspects in the video cases, as they are envisioned as prompt for teachers to focus their learning on specific pedagogical dimensions in the lessons. In a similar fashion as video cases were rated, most teachers rated the relevance, usefulness, and user-friendliness of guiding questions as average (42 – 44%) and good (46 – 49%). It seems that the guiding questions have helped the teachers to achieve learning objectives but the relevance and usefulness of the questions could be increased based on participants' feedback. (Table omitted)

Results on teachers' perception of collaborative space in discussion forum show that they also view its relevance, usefulness, and user-friendliness as between average (40 – 50%) and good (37 – 48%). There were a few teachers who rated it *very low* (2 – 4%) which suggest that learning potential of discussion forum is still yet to be enhanced and encouraged. (Table omitted)

In addition to the physical usefulness of the forum, teachers generally found that sharing their reflections in the forum is beneficial for their learning. They rated relevance, usefulness, and user friendliness of their sharing by posting their individual reflections in the online forum as mostly average (43 – 49%) and good (41 – 47%). As personal sharing is at the heart of PLC building, this rating shows a good start as generally teachers have felt comfortable with this sharing and noticed its learning potential. (Table omitted)

Following the personal sharing is discussing among colleagues on each other's sharing. In order for the collegial commenting and sharing to be effective, teachers must first feel comfortable and find it useful to learn from other people's comment and crique. The initial response is quite promising as most of them rated its relevance, usefulness, and user-friendliness as average (38 – 43%) and good (43 – 48%). (Table omitted)

Overall, it shows that teachers are quite receptive with this new learning environment and have noticed potentials in using it for their professional learning. To get deeper insights into teachers' perception, their qualitative comments were also collated. The comments were then categorized into positive responses (yes), neutral responses, and negative responses (no). There are 6 broad categories of qualitative comments: usefulness of video cases, the extent in addressing teachers' learning needs, quality of guiding questions in facilitating video viewing, clarity of guiding questions, teachers'

comfort levels in using the e-learning environment, and cross-level relevance for lower and upper primary teachers to watch a video case from P6 classroom. (Table omitted)

Teachers' responses in all the six categories are mostly positive. More than 80% acknowledged the usefulness of video cases to their learning, the quality and clarity of guiding questions, and cross-level relevance. This shows that teachers who do not teach the same grade level as the case teacher's in the video still find it relevant to watch the lessons for their own learning. However, in terms of addressing teachers' learning needs, only about 63% felt its benefit. Among those who rated beneficial, teachers enjoyed the benefit of learning from other teachers' instructions and pedagogical approach as well as shared the same interest in how the bridging should be done at primary school level. Among those who do not feel the benefit yet, the main reason is these teachers did not teach mathematics, hence no specific need to study deeper on the bridging topic. One teacher noted that beginning teacher will benefit more than experienced teachers in learning from the case teacher's video cases. Teachers' input on guiding questions suggest some possible improvement in terms of simplifying the sentences, better classification of the questions, and the need to have general questions for those who do not teach mathematics. In terms of comfort level, although most teachers felt comfortable, some points were raised including separating private and public thoughts and concern with non-anonymous posting.

Last, the teachers were asked about the technical difficulties that they experienced. About 35% of teachers said they did not have any difficulties with the e-learning. The highest difficulty experienced is the problem in logging in (28.75%) due to limited password retrieval system. About 12% mentioned slow speed of playing the video, which is attributed to limited server space and having many users accessing it at the same time. About 17.5% expressed the need to simplify the navigation. In the 4 months (Dec 2010 – April 2011) following the survey, improvement has been made as much as possible in successfully addressing all these difficulties.

2. Analysis of the Online Forum Discourse

Following the viewing questions, the teachers were engaged in 1) describing the case teacher's approach to bridging; 2) make comment based on their own personal knowledge; and 3) reflect upon their own teaching practices. The following example is a typical way how teachers described and made sense of the case teacher's lessons in bridging algebra and the model method.

> *Teacher uses the model method which the pupils are familiar with and parallel it to the algebraic method. In doing so, pupils can see that model drawing and the algebraic method are just simply 2 different ways to represent the information given in the question and to deal with it.*

Following the describing, the viewing question asks the teachers to comment on the case teacher's teaching and relate to his or her own teaching of the same topic. Our analysis shows that the teachers were able to compare this lesson to a regular lesson in which concrete and specific material is used to help children understand more abstract concepts and relate the teaching to the general principle of the concrete-pictorial-abstract model in teaching. Most teachers expressed that they

would use the same approach to teaching a similar topic. This indicated that watching and describing the videoed teaching both helped teachers to relate to general teaching principles, critique on certain point based on their own individual observation, relating the teaching to secondary school math teaching and find an expression for his or her own beliefs in the bridging effort. In doing so, their tacit knowledge were made more explicit. An except is given below:

> *To me, I like to reckon it to the different 'languages' in Maths. Something similar to decimals vs fraction vs ratio vs percentage vs unitary approach which are just different ways in which information and data can be represented. In doing so, pupils begin to see algebra as less abstract. I would think it is something similar to when we teach new concepts, …. If I were to conduct the same lesson with upper primary students, I would do about the same thing, …*
>
> *However, I felt that there is, I should say, an overemphasis on intermediate statement that baffled me too. Certain time I thought that the pupil has given the correct intermediate statement which is not accepted by the teacher. In a certain way, I felt that this can intimidate the pupil.*
>
> *Yes, my understanding of bridging is the same as the teacher. I think it is good and necessary to do it at the primary school level. In secondary school, the teacher would not have the time to show the bridge between the two approaches and the linkage that pupils could have discovered through such lessons would never be discovered by the poor students. By providing such lessons, we are also providing the students with another approach to tackle their examinations. I always believe that it is better to have more ammunition than less and it is a real fact that some students will take to a certain approach more than others. It will only benefit the students in the long run.*

These three excerpts represent views generally present in all teachers' responses. This suggests that the viewing or guiding questions have effectively engaged teachers to view and consider these three aspects in analyzing the case teacher's video, which otherwise might not happen if they were to view the video without any prompts. As mentioned earlier, the teachers were also able to critique on the case teacher's practice, which triggers deeper thoughts and discussions on knowledge building of bridging.

Findings from what the teachers would do if they were to conduct the same lessons show that 18 teachers would like to use similar approach to the case teacher's approach. This suggests that the case teacher has demonstrated an approach that may serve as an demonstration example for other teachers to adapt. In addition, the following two different approached were also suggested by two teachers: shared more insights on conducting the segment differently from other teachers: first, solving algebraic equation approach, and 2) using other means to bridge concrete/pictorial to symbolic, such as using manipulative, using pictorial representation to indicate "x", the unknown, or use bracket do indicate a missing number to fill in. In addition to the rich approaches shared, some teachers also indicated improvement needed in the variety of activities, such as having students discuss and draw their own models first before teacher introduces his examples, use pair work to "elicit the link between the

model method and algebra" and "allow pupils to explore the algebraic method further through pair work".

3. The important role of an e-facilitator

To ensure knowledge co-construction in the e-learning, the role of facilitator is vital. The following excerpts show how facilitator helps to bring discussion into deeper level.

Speaker	Discourse	Action
Initiator:	I would start with a method that they are familiar with (model method) then using the same question, show the pupils how to do it with algebra. (same as the video) As an extension to it, use a parallel question for them to answer with algebra method.	Teacher's sharing of practical personal knowledge
Facilitator:	In response to Q3, I agree that using a parallel question will help the pupils practise how to apply the new method (algebra) learnt. When doing the parallel question, will you also show them the model method first or will you use the algebra method directly?	Commenting on and inviting the initiator to elaborate his point
Initiator (Response):	I will get them to answer using the model method first to see if they know how to use the model method that has been taught with it. Then try it using the algebra method. They can decide which is the method they prefer and can use it in the future. A worksheet with 3 questions can be given but they are to only use the algebra method to solve the questions.	Teacher's elaboration of her shared practical personal knowledge

The above excerpt shows that a facilitator role is important to induce teacher's further elaboration of shared personal knowledge. Without the trigger from the facilitator, the depth of sharing cannot go beyond what has been initially written and shared. Which is why it is important for a facilitator to be sensitive to the need of further elaborating on an idea to benefit the whole community.

Another example shows a contrasting role of e-facilitator. When a discussion has been flowing *naturally* and does not need help to deliberately induce elaboration, the facilitator positioned himself or herself as a teacher participant and used his or her personal knowledge to enrich the discussion and lead to knowledge co-construction.

Speaker	Discourse	Action
Initiator (Teacher A):	The students would be able to relate algebra to the model method which they are already familiar with. By going through the answer using the model method first and then leading the students to solving the problem using the algebra on the other side of the board. The students would be able to see how similar the working for the model method and the algebra method is and they would be able to relate to it better.	Teacher's sharing of personal knowledge
Teacher B	I totally agree with you Mr A. But what if the students are even confused after seeing both methods?	Colleague B's reply opens up further examination of teacher A's idea.
Teacher C (Respond to B)	I think it's totally alright for pupils to be confused when presented with 2 methods. You need to have imbalance before you attain equilibrium :) As pupils gets more exposed to this way of teaching where different methods are always discussed and presented, then they will eventually see the benefit of it. Of course, what we, teachers, need would be a lot of time, so I guess we can only do this for selected questions. Maybe, one or two per week would be good?	Colleague C's reply to colleague B. The reply is based on colleague C's personal knowledge and offers a possible solution to the problem raised by teacher B.
Facilitator (brought up new issue)	Do you think that pupils of all abilities are able to see the relationships and grasp the concept? Or is it only applicable for the higher-ability pupils?	Facilitator probed further by bringing up a more specific and challenging issue
Teacher A (Response to facilitator)	Actually personally I feel that the higher ability pupils will be able to grasp the topic better. The lower ability pupils will definitely have a problem understanding perhaps we could show in a graphical format? perhaps it would be easier for the lower ability students to understand.	Teacher A's reply to facilitator. Further sharing of his personal knowledge.
Teacher D (response to A)	Yes yes, Mr A.. Graphics definitely work better for the weaker children. If you are able to use concrete examples to show them and illustrate	Another colleague, Teacher D, replied Teacher A, which strengthened Teacher A's argument.

	to them, they are able to understand and see the light at the end of the tunnel then…	
Teacher E (response to D, initiate new issue)	How often do you see us bring manipulatives to classroom for lessons? How often has the Math Room been utilised for hands-on session? I am also guilty of assuming that the children have a certain level of understanding and jump straight into concrete examples. Even bypassing pictorial examples!	Teacher E joined the discussion by responding to Teacher D's argument. At the same time, he also brought up a new issue. The issue is also based on Teacher E's personal knowledge.
Teacher F (elaborate new issue)	I believe that weak children who have poor understanding of the concepts and have difficulty in the model drawing approach would be not able to understand the algebraic way. They will be utterly confused.	Teacher F joined the discussion by elaborating the issue raised by teacher E.
Facilitator	I agree with Mrs F that the concept of algebra may be a little too abstract for the weaker pupils. They may end up being more confused.	Facilitator acted as participant to strengthen the point made by the discussants.
Teacher G	Yes, some weaker pupils may already have difficulties understanding the model concept and by going a step further to introduce the algebraic method to these pupils, I wonder if that will confuse the pupils even more.	Another colleague, teacher G responded to facilitator's reply. It seems that facilitator reply has invited deeper discussion on this issue.
Teacher H	The model method is already the most basic from of algebra so I think it is only a natural progression if they can see through the abstract portion of it.	Teacher H's brought up his personal point of view, can also be viewed as sharing personal knowledge.
Teacher I	I disagree. By right, it should relate to the model method. However, the unknown 'x' was not resolved, leading to possible confusion.	Teacher I counter argued to teacher H.

This is an example of rich discussion that invites more and more participants to contribute ideas based on their own personal practical knowledge. It could be seen that sometimes they shared common knowledge, but at other times they have different points of view on the same issues. If the discussion continues, the trend will lead to deeper understanding of the issue approached from many angles.

DISCUSSION AND CONCLUSION

As a design-based research conducted within a short duration of less than two years, the analysis, design, testing, refining were often overlapping in the same

phases of our work, reflecting the intensivity and the demanding nature of this kind of research and intervention. When design is at the core, the Project focused on stabling the design, making the tools and platforms user-friendly through piloting its use and making adjustment. All this work, when done well, will eventually take full advantage of video and online technology to engage a large number of teachers within and across schools sharing their analysis of authentic classroom discourse, reasoning with pedagogical decisions and actions of the case teachers and building knowledge about the teaching and student learning of the subject matter at any time and any place networked through the Internet.

Given the nature and focus of the Project, there are several unique features about the project that made its spread and capacity building different from other projects. First of all, the authenticity of the local problem of bridging algebra learning represented in the video case of a local teacher's classroom has triggered rich reflection and discussion among the teacher participants (all the English-media teachers in the school). According to our survey, 85-91% of the teacher participants surveyed (N=80) regarded that responding to guiding questions of the video cases, sharing, discussing their responses in online discussion forums and the e-facilitation are relevant to their teaching, useful and user friendly. Our analysis of the emerging online discourses demonstrate observable patterns of teachers building upon each other's ideas, relating the case teacher's teaching to their own classrooms and in some cases trying out the case teacher's strategies in their own classrooms and sharing online what they learned from their trials.

The ongoing enhancement of our learning tools and environment will allow teachers to upload their own video cases about their own practice (for instance, from their own lesson studies) for colleagues' viewing, critiquing, analyzing and providing feedback. The current piloting is moving teachers from responding to given questions from researcher-identified clips to teachers choosing their own 'critical incidents' and articulating and sharing their rationale of choice from the available video cases. We believe that by doing so over a sustained period of time, teachers would become ready to upload their own research lessons from the school's lesson study work and identify their own critical incidents as avenues for developing ways to improve teaching and eyes to see children's learning and thinking. A sustainable ecosystem of online learning could be built in this way.

With lessons from the daily classrooms of one teacher's self-initiated attempt at bridging to "offer my pupils the best of both worlds (arithmetic and algebra through the model method)" (interview with the case teacher), a perennial learning issue worldwide was then represented in ways to capture the unique local context of the problem and was thus able to trigger rich discussions. From teacher responses, we found that, when teachers were engaged in describing the teaching situations and interactions in the video cases and then relating to their own practices, they were making serious effort to understand a colleague's teaching and reflect on their own teaching. Including the case teacher's interviews in the video cases and having him play the dual role of a facilitator and co-participant in the Forum also helped other participants to make better sense of his thinking, realize what was going on behind the classroom scenarios portrayed in the video cases and verify the truth of the claims they made about the video cases in the forum discussions (Koc et al, 2009).

Our analysis so far shows that authenticity and careful design for anchoring informed by systematic review of design theories and earlier research as well as ongoing teacher feedback was a key factor in promoting the initial success in the emerging knowledge and community building in the pilot school. This shows that the school has demonstrated a strong sense of ownership. For instance, during piloting of the video cases development from 2004 classroom videos (January – April 2010), the school came up with their own implementation plan: they identified the Math Committee members to be the school's internal facilitators and used contact time to provide them with face-to-face sessions led by the case teacher to get them familiar with his classroom teaching videos. After a training workshop on e-facilitation skills provided by the researchers, they were introduced to use the video cases and online learning platforms.

When piloting the 2010 video cases, the school identified a number of general concerns of all English media teachers (such as lack of careful classroom culture building) and provided all the English-media teachers with two face-to-face sessions on Seat Work and Classroom Culture facilitated by the video case teacher before moving them to the video cases and the online forums facilitated by the Math Committee members. In this way, a natural blended learning model was formed by the school showing their strong sense of ownership. Teachers started to share the same belief held by the case teacher – if their students are capable of choosing between the model method and algebra approach according to the nature of a given word problem (rather than relying solely on the model method), they would benefit much more in their long-term learning and more practically in the Primary School Leaving Exams (PSLE), the high stake exams determining which secondary schools their students are going to be promoted to at the end of Primary 6.

Our research, development and implementation experience strongly illustrates the importance of research-based development of tools and processes to inform practice and policy. Since such studies share an immediate concern about its impact on practice, we strive to generate good solutions to practical problems in teaching and learning. As Schonfeld (2006) advocated, we built on findings from earlier research but, we have gone beyond them, by building and implementing a prototype platform and tools for teacher learning in Singapore. We continue to conduct rigorous evidence-informed evaluation to help sustain the knowledge and community building effort in addressing the bridging issues. Further implementation and research is going on in a follow-up funding cycle to drawn on implications for use in diverse school contexts (including use in pre-service coursework) and learning platforms (such as formal online courses). In the meantime, we have to face the widely-acknowledged challenges in conducting such time-consuming and long-term projects that commonly have a longer waiting time to yield data and results for academic sharing purposes and more difficult to sustain. However, with our firm belief in its value for innovation and its direct application to improve practice, we strive on.

The iterative design and continuous improvement process has strengthened our understanding of what constitutes rich and educative video and multimedia cases and how to best use interactive digital media and online technology to effectively support teachers in teaching and learning through mathematical problem solving. As researchers and designers, we strive to find better technological support to improve the online learning environment. We are aware that it takes time and support as well

as continued research to nurture and sustain an online community for knowledge building.

Last but not least, the collaboration with the case teacher's school has built the research capacity of the case teacher and the school's staff development personnel. The case teacher wrote a paper on his own bridging attempt in teaching the unit in his primary 6 classroom (see Appendix C) and together with the school's staff developer they wrote about the school's implementation of the online PLC building processes (Appendix D). Together with a researcher's analysis of the discourse patterns of the case teacher's lessons (Appendix E), the Project findings reported above, these papers were presented in a symposium at the recent 4th Redesigning Pedagogy Conference at National Institute of Education.

Future Directions

Moving towards the future, the Project is planning to take the design further through continued enhancement of the functionalities to build in capacity for teachers to upload their own video clips, do their own video annotating to promote teachers' sharing and knowledge building. Building upon the PI's experience in leading lesson study work in local schools, such enhanced video functions and sharing tools would be highly beneficial to the founding of a Lesson Study Centre at NIE in supporting the increasing number of teachers in their lesson study initiatives, such as in the collaborative online planning, sharing of material and videos through online repositories.

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