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Advancing understanding using Nonaka's model of knowledge creation and problem-based learning

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Abstract Nonaka's model of knowledge creation can provide guidance for designing learning environments and activities. However, Bereiter is critical of the model because it does not address whether understanding is deepened in the process of socialization, externalization, combination and internalization. To address this issue of understanding, this paper proposed a framework that synthesizes the basic phases of problem-based learning with Nonaka's model. This paper reports on a study investigating if a course designed based of this authentic framework can help to stimulate knowledge creation that is based on deepening understanding. Several types of data were collected in this design-based research, namely: reflections by the participants and instructor; group discussions; student-created artifacts; and, documents, records and artifacts that reflect the overall design of the course. The findings suggest that the participants demonstrated advancing understanding amidst knowledge creating conditions and processes consistent with Nonaka's model. Other key implications are also discussed.

Keywords Knowledge creation · Understanding · Problem-based learning

Introduction

How does one go about learning the necessary knowledge to manage a multinational organization or to teach a class of teenagers using technology? Studies (Tee and Karney 2010; Tee and Lee 2011) suggest that Nonaka's model of knowledge creation (Nonaka et al. 2001) can provide some guidance. Additionally, Paavola, Lipponen and Hakkarainen (2004) argue for a "knowledge-creation" approach to learning, rather than limiting learning to the two approaches of acquisition and participation, as described by Sfard (1998).

However, Bereiter (2002, p.158–168) was critical of Nonaka's model of knowledge creation. He argued that a key weakness of Nonaka's model is that it offers "nothing about understanding and depth of understanding" (p.161). This is crucial, Bereiter argued, because

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fundamental understanding is what differentiates knowledge building from blind luck or serendipitous imitation.

This paper reports on a study that attempts to describe how Nonaka's model can be improvised by integrating a problem-based learning approach to stimulate knowledge creation, and, if and how deeper understanding is cultivated.

Framing of this study

Nonaka (with Takeuchi, 1995; with Toyama & Byosiere, 2001) suggested that knowledge can be created and shared through socialization, externalization, combination and internalization (SECI). It is an interactive rather than a sequential process resulting in the creation of new knowledge. *Socialization* is a process of sharing experiences that are often context-specific and difficult to formalize or make explicit. Sharing can take place through observation and talk in the midst of common experiences. *Externalization* is a process of articulating further knowledge that is difficult to formalize or make explicit. Representations of knowledge crystallize through more precise language, objects or praxis enough to be shared with others. *Combination* is a process of breaking down and organizing discrete elements of externalized knowledge into a more systematic whole so that it can be disseminated to others in different contexts. *Internalization* is the process of embodying knowledge through practice, action and reflection. In addition, Nonaka, Toyama and Byosiere (2001) held that these knowledge conversions must take place in a *ba*, a Japanese word that basically means a dynamic shared context. This *ba* is designed to energize knowledge creating activities by providing enabling conditions and places of autonomy, fluctuation and creative chaos, redundancy, requisite variety, trust and commitment. The SECI process is not limited to one ontological level, in that it can involve different levels of knowledge-creating entities including individuals, groups, organizations and interorganizations (Nonaka et al. 2001).

Tee and Karney (2010) suggested from their study that Nonaka's model of knowledge creation could be used as the basis for designing effective learning activities and learning environments. However, Bereiter (2002) argued that Nonaka's model does not account for understanding.

Bereiter (2002, p.158–168) was critical of Nonaka's model for education as well as for organizational knowledge management, the area in which the model was first established. He argued that understanding is the crux of expert knowing, and a model that does not explicitly address the issue of understanding is fundamentally flawed. In a story made famous by Nonaka's work, an engineer—tasked to develop a bread-making machine—observed and practiced the kneading actions of a master baker and was soon able to convert it into a physical prototype form. This, according to Bereiter, can be attributed just as easily to "dumb luck" (p.161) or fortunate imitation.

The concept of understanding can trigger off many different arguments. To facilitate this discussion, this study used basic indicators of understanding based on Bransford, Brown and Cocking's (2000, pp.8–13) work. They described five key indicators of advancing understanding. Initial understanding may begin knowing and stating appropriate facts and knowledge about subject matter. Then as understanding grows, the learner may be able to detect and reduce error of facts or weak arguments. He may then begin to be able to relate between structure, function and context, followed by a growing ability to transfer to other contexts, and still more advance, to generate and justify predictions.

In Tee and Karney's study (2010), there were indicators of such advancing understanding particularly with learners who said that previously inert concepts came to life as they engaged in what was eventually framed as SECI cycles. The SECI cycles were triggered by a simulation

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that entailed managing a global shoe company riddled with different challenges. The learners functioned as the senior management team to make weekly strategic decisions involving finance, marketing, manufacturing and so on. During this process, each decision had to be argued based on data they had access to and how it advanced their strategic plan. It was in this context that the collaboration led to active SECI cycles and consequently the advancement of their strategic management understanding.

The main essences that need to be highlighted are: a triggering complex reality-based simulation or scenario, and collaborative negotiations that lead to decisions that are subject to be tested and re-tested in a dynamic context. These are characteristics that are consistent with the basic premises of problem-based learning (PBL), which is to situate learning in inquiry-based, collaborative, iterative, reflective and self-directed problem-solving contexts (Hmelo-Silver 2004). A fundamental goal of organizing PBL learning activities and experiences is to advance students' understanding of concepts through problem-solving activities accentuated by a deliberate and reasoned decision-making process (Greeno et al. 1996; Hmelo-Silver 2004; Schmidt et al. 2012; Tan 2003). It is by integrating these basic foundations of PBL with Nonaka's model that brings the issue of understanding to the foreground rather than to be confounded in the background. In addition, the PBL approach can also function as a process guide for learners as well as for the instructional designer.

The knowledge domain in the context of this study is technological pedagogical content knowledge, or TPACK (Mishra and Koehler 2006), a framework built based on Shulman's (1986) seminal work on pedagogical content knowledge. In essence, a teacher who has cultivated advanced TPACK will exhibit a nuanced capability to critically choose or design and configure, learn, and apply the technologies that will best meet the teaching and learning needs within their context.

In the context of TPACK, problems or situations that teachers deal with can be ill structured (Koehler and Mishra 2005) or wicked in nature (Rittel and Webber 1973). PBL problems in science-based subjects tend to have a finite number of possible solutions. Teaching and learning problems, on the other hand, can be dynamic and can be in constant flux. For example, a theoretically good solution to solve a problem can, when implemented, eventually cause the very nature of the problem to evolve. For this reason, the PBL phases in this study will have a lengthened timeframe so that learners can have opportunities to deal with wicked problems iteratively.

In other words, with Nonaka's model as a backdrop to stimulate knowledge-creating conditions and processes, problem-based learning can be used as the basic approach to drive understanding and the development of TPACK (Hmelo-Silver 2004;). As a process, PBL can be encapsulated by five basic phases: IDEAL, as in "I" for identifying problem; "D" for defining problem; "E" for exploring solutions; "A" for acting on proposed solutions; and "L" for looking back and evaluate (Bransford & Stein, 2002). As illustrated in Fig. 1, while learners engage in the PBL phases, they will also be encouraged to engage in socialization, externalization, combination and internalization in a stimulating shared context. The learning context is designed to have the essential *ba* qualities to encourage knowledge-creation activities.

For example, in the "Identifying problem" phase ("I" phase), learners talk about and describe the problems or issues they are facing. During the beginning of this phase, the dialogue is deliberately informal and relatively free flowing, allowing for sharing of feelings, emotions, experiences, and ways of thinking. For this to happen, the context needs to be relatively open and risk-free. This is consistent with the notion of socialization and its enabling *ba* (Nonaka et al. 2001; Tee and Karney 2010). As the "I' phase progresses, there is a need to begin to articulate the nature of the problem a little more—and this can happen with an appropriate externalization *ba*. At some point, different articulations begin to emerge. These different ideas

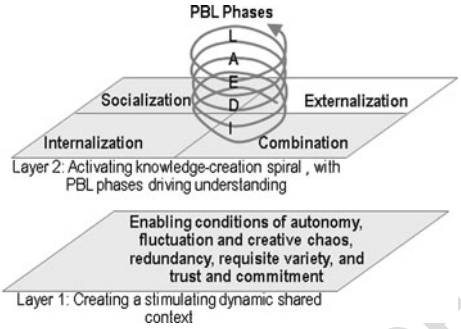

Fig. 1 Combining Nonaka's model of knowledge creation and PBL to drive understanding

needs to be organized and synthesized in some way, shape or form—giving way to what Nonaka refers to as combination. The *ba* here works to ease the organization of ideas so that it can be shared more easily with others. As the discussion deepens towards identifying the problem more precisely, deeper reflections may be triggered or may occur spontaneously. This opens up opportunities for internalization. At some point, the 'I' phase will mature and move on to the subsequent phases. It is important to note that while the IDEAL phases progress in a largely linear fashion, the SECI process can be quite non-linear or interactive.

The integration of the PBL approach into Nonaka's model makes explicit a critical layer of problem-solving dialogue and action that drive intentionally toward deeper understanding. This creates opportunities for learners to focus on an authentic and complex problem and then seek ways to critically evaluate, choose and use emerging knowledge to address the problem. A key part of this process is to critique or be critiqued to identify gaps in thinking, and consider patterns and principles of thinking that can be used in different situations. Simultaneously, Nonaka's model can be used as a guide to design the kinds of activities and create the kinds of conditions to stimulate knowledge creation. In this context, amore specific guiding research question emerged: If a course is designed based on this framework, how do these knowledge creating activities play out in a way that helps advance understanding and develop TPACK?

This research

Research context

The students were enrolled in this 14-week module in a master of instructional technology program. The objective of this module is to help students develop know-how in designing, selecting and applying appropriate technology in different learning contexts. In other words, the goal of the course is to help the students develop technological pedagogical content knowledge. The students of this course comprised 18 in-service teachers, with their ages ranging from mid-20s to early 40s. They taught at elementary, secondary and tertiary levels, in varying subjects including language arts (English language, Arabic, and Chinese language), social sciences (history, living skills, and IT), Sciences (Chemistry and Biology) and Mathematics. Fifteen of the eighteen participants were women. All of them have been teachers for at least 1 year, with an average of 8 years experience. However, for reporting and discussion purposes, the focus will be on Group A because it had the most in situ data and developed the most convincing solutions. The criteria for this selection are discussed further in the methods section.

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Course design

The course was designed based on the proto-theory synthesized in Fig. 1. The *ba* was operationalized in a number of ways to facilitate the problem-solving phases through socialization, externalization, combination and internalization. Students were given the freedom to act with relative autonomy so that they will be more motivated to experiment and discover new knowledge. Significant fluctuation and creative chaos were expected to grow from the deconstruction and reconstruction of rich and ill-structured real-world complex problems, largely to allow for the breakdown of old, encrusted mental models and routine behaviors to make way for new ones. Numerous information sources were made available to the students that went beyond what they were accustomed to. This kind of information redundancy was expected to force students to learn to discriminate the most critical information from the less important information. To account for the principle of requisite variety—which calls for internal diversity to match the variety and complexity of its external (or the real) environment—the rich and ill-structured real-world complex problems as part of PBL became an essential part of the design milieu. After all, effectively integrating technologies in the classroom is in itself "a complex and ill-structured problem involving the complex interaction of multiple factors, with few hard and fast rules that apply across contexts and cases" (Koehler and Mishra 2008, p. 10). And finally, a culture of trust, care and commitment—such as honest but respectful communications and constructive feedback—was emphasized and practiced whenever possible.

In this regard, the situation as well as the individual and group processes of knowledge cultivation must be allowed to emerge through socialization, externalization, combination and internalization so that it can be subject to feedback, improvement and change. In other words, knowledge can be cultivated through a series of social interactions, personal reflection and insight, and through different forms of experiential learning, where one's actions or communications are recursively emphasized as new layers of knowledge are conceived (Tee and Karney 2010).

The design of the course was operationalized into four chronological segments. The first 4-week segment was to give students time to frame and define the problems that came directly from what they were facing in their real life-teaching context. The problems had to be directly related to teaching and learning (as opposed to say, policy or administrative issues or purely technical problems). The problems must be complex, as opposed to being too simplistic (for example, the LCD projector in the classroom is unreliable). The problem preferably had to be common or similar to what is being faced by at least two other people. The students worked in teams based on the specific problems they chose to own and work on. As highlighted in Table 1, group-based online discussions were done in GoogleWave and the discussions were self-directed. This was essentially to allow for socialization and externalization. Internalization was encouraged through weekly reflections on actions they were engaging in.

Soft as well as hard scaffolding were used to facilitate the PBL process (Hmelo-Silver et al. 2007). A wandering facilitation model was utilized primarily for soft scaffolding purposes (Hmelo-Silver 2004). Two key readings—on TPACK (Mishra and Koehler 2006) and on GPM, or giving, prompting, and making pedagogical approaches in relation to TPACK (Hammond & Manfra)—were used as a form of hard scaffolding to help ground and frame discussions within the context of using technology in teaching and learning. The know-need-do table was also used as scaffolding tool.

The second 4-week segment was for the teams to consider different solutions, propose and select a solution. The third 4-week segment was for each group to implement the selected solution in a pilot or full-blown situation, and subject it to further evaluation during class discussions. The fourth and final 2-week segment was for students to present and discuss the process and outcome of the entire learning cycle.

t1.1 **Table 1** Enabling conditions (*ba*), processes and activities to stimulate SECI and supporting technology

t1.2 Enabling conditions (*ba*)	Knowledge-creating Processes	Activity	Supporting technology
t1.3 Autonomy t1.4 Fluctuation and creative chaos	Socialization Externalization	In-class (facilitated by instructor) and online discussions (self-directed) throughout the IDEAL problem-solving phases	GoogleWave—group-based synchronous and asynchronous discussion platform
t1.5 Redundancy	Combination	Electronic book (e-book) chapter to chronicle each groups' story throughout the IDEAL problem-solving phases	GoogleWave—ongoing group-based wiki-like collaborative writing plat form. Viewable by other groups, but can only be edited by group members.
t1.6 Requisite variety t1.7 Trust and commitment	Internalization	Reflecting on issues and actions (based on IDEAL phases) in weekly individual reflections and semester-long, group-based e-book assignment.	GoogleWave—weekly individual reflections.

As they proceeded in the IDEAL phases, they were asked to chronicle their stories in a chapter of an electronic book (e-book) assignment to describe key issues, actions, and challenges. They were also asked to provide evidence or justifications for whatever key conclusions they were making. This was essentially to allow for externalization and combination.

Throughout the semester, approximately two of the 3 hours of each class session was used to share findings, reflect and, suggest and justify ways forward; and the remaining time was mostly used for self-directed collaborative meetings. The in-class discussions were used to accentuate the importance of evidence-based discussions and actions, and as live models of healthy socialization and externalization.

In summary, each group was required to write a chapter in an e-book project using a GoogleWave page to document their on-going experience during the course (Refer to Fig. 2, right window). The page was accessible to all members of the class, but edits could only be made by respective members of each group. Synchronous and asynchronous discussions also were done on the same GoogleWave page (Refer to Fig. 2, left window). In addition, they were also asked to write weekly reflections. GoogleWave was the technology of choice as it allowed for all the major activities (discussions, e-book, reflections, sharing of resources) to be done in one integrated platform. In addition, it also seemed to allow for natural conversations and collaboration to occur in one place—including interjections in mid-sentence, real-time and asynchronous text-based chat abilities, as well as wiki-like and blog-like functions(Refer to Fig. 2). (Note: GoogleWave is now defunct. It was released on a limited basis in late 2009, then to the public in May 2010, and was shut down by the end of 2011. The use of GoogleWave in this course took place in 2011. The innovations in GoogleWave have been adapted for use in other Google tools.)

Method

This research was conducted using a design-based research process. The research context—in this case, the course—is subject to an iterative process of designing, developing, implementing,

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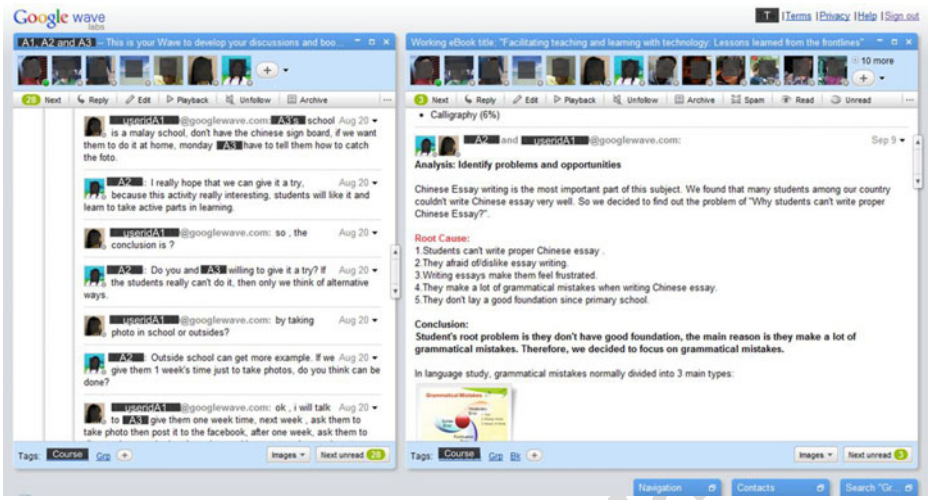

Fig. 2 Screen shot of the GoogleWave-based course site (left window for group discussions; right window for e-book assignment)

testing, investigating, and refining over two implementations (Design-Based Research Collective 2003; Barab and Squire 2004; Wang and Hannafin 2005). This paper is reporting on the second implementation based on further refinements after the first implementation (Tee and Lee 2011). Refinements were done at two levels—the design of the learning environment and the methodological level. At the learning environment level, a switch to GoogleWave was made to help facilitate knowledge creation activities in a single platform. As mentioned earlier, all the major activities (discussions, e-book, reflections, sharing of resources) were to be done ideally in one integrated platform. The choice of GoogleWave also helped address a key issue at the methodological level, in that it increased the chances of capturing in situ knowledge creation activities. The pedagogical design remained largely the same as the first iteration was quite successful (Tee and Lee 2011).

The design of the overall learning environment is highlighted in Table 1 and the guiding proto-theory is illustrated in Fig. 1.

Four types of data were collected, namely: reflections from the participants; student-created artifacts such as the e-book writings and discussions in GoogleWave; documents, records and artifacts that reflect the overall design of the course; and, reflections by the instructor. These data were used primarily to capture knowledge creation activities in situ. In this study, credibility was addressed with four techniques—triangulation, prolonged engagement, persistent observation, and referential adequacy (Lincoln and Guba 1985). In terms of referential adequacy, all data analyzed was captured and documented in its original form.

The data were coded by two coders until consensus was reached. First, two individuals separately coded the data in units most descriptive of knowledge creating processes and conditions. Then these units were reviewed and revised based on the consensus of the two coders. Consensus was developed based on the primary question: what is the best way to describe this line or paragraph of data? The units were then consolidated into categories by mapping to the SECI model. The intention was not to force the units into SECI, but to attempt to give SECI more definition. The patterns emerged most clearly at the category level.

For example, instances where there was the unit coding of "sharing of experiences," "sharing of feelings" or "sharing of mental models" was mapped to the "socialization" category. In

addition, it was observed that such exchanges tended to be less formal, and where actors did not demand evidence or clear justifications. The exchanges that demanded more evidence and clearer justifications such as the ones involving articulation or clarification of ideas and counter ideas, argument for or against an idea and evaluation of ideas were mapped with the externalization category. The final key codes are described in Table 2 and Table 3.

Understanding was judged based on indicators described by Bransford, Brown and Cocking's (2000, pp.8–13), as discussed earlier in the framing of this study. Figure 3 is a sample of how understanding was judged.

The reporting of the findings in this paper focused on the group that produced the most in situ data that allowed for detailed analysis and also developed the most convincing solutions. The participants were not required to interact online exclusively on GoogleWave, in line with the autonomous ethos. As a result, they interacted on platforms that they felt most comfortable with—some did it on Facebook and email, and others met in face-to-face meetings. The researchers did not have access to these data. Group A happened to do a lot of their communications over GoogleWave. In addition, we wanted to study the activities of the more successful groups as a starting focal point to respond to the research question. While there is room for a comparative study between a successful and a less successful group, the data would have to be available for both groups. In this case, there were some limitations as the type and depth of data available for each group were different.

Findings and discussion

Group A consisted of three in-service teachers: A1, A2, and A3 who teach language arts (Chinese) in high school. A1 has been teaching for 16 years, with minimal use of technology. A2 has been teaching for 14 years, and has been exploring different technologies with limited success. A3 has 20 years of teaching experienced, and has never really used technology to enhance learning. The problem they chose to focus on: their students' struggle in writing essays in Chinese, a second language for most of their students.

The following discussion will be based on the basic phases of problem-based learning that the group went through, and corresponding connections will be made to the emerging *ba*

t2.1 **Table 2** General coding scheme for knowledge creation processes

t2.2 Units	Key categories
t2.3 i. Sharing feelings and emotion ii. Sharing experiences iii. Sharing mental models	Socialization
t2.4 i. Clarification dialogue—for clarifying common terms or concepts including defining and/or describing characteristics of a situation towards shared understanding ii. Articulation of need or a request iii. Articulation of options or new ideas (for consideration) iv. Argumentation for a proposal or idea v. Argumentation against a proposal or idea vi. Agreement (including agreeing to agree, or agreeing to disagree) vii. Evaluative dialogue before implementation	Externalization
t2.5 i. Drawing on multiple knowledge sources ii. Breaking down of concepts into meaningful parts for re-synthesis or re-presentation	Combination
t2.6 i. Action and practice ii. Evaluative reflection during or after action	Internalization

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t3.1 **Table 3** General coding scheme for knowledge creation conditions

t3.2	i. Indicator of developing a sense of responsibility for own learning and actions	Autonomy
t3.3	i. Breakdown of routine, habits or cognitive frameworks in the face of fluctuating or chaotic conditions	Fluctuation and creative chaos
t3.4	i. Existence of information that goes beyond the immediate requirements of the individual or the group (lots of ambient information; the information may or may not be important)	Redundancy
t3.5	i. The internal diversity of a class matches the variety of complexity of the real environment. ii. Catalysts or ethos for different perspectives to be considered.	Requisite variety
t3.6	i. The way the individuals treat and feel about each other	Trust, care & commitment
t3.7	i. A sense of mutuality that creates a galvanizing sense of energy or purpose	Sense of mutuality

and SECI layers of knowledge creating conditions and processes (please refer to Fig. 1 as well as Tables 1 and 2).

Emerging *ba* in the process of identifying and defining a problem

In the first 4 weeks of this 14-week module, the teachers were asked to talk about the problems they faced in their classrooms. Initially, there was reluctance to share openly and deeply. But as they began to hear each other's stories, more began to open up. Soon after, the participants began to speculate about different causes: the students were uninterested, or that they were just lazy. Or, that they were afraid to write for the fear of making mistakes. Socialization and externalization took place actively during these face-to-face discussions. What stood out was their sense of despondency and honesty as they attempted to define the problem that they were facing, as can be seen below on August 6 reflections:

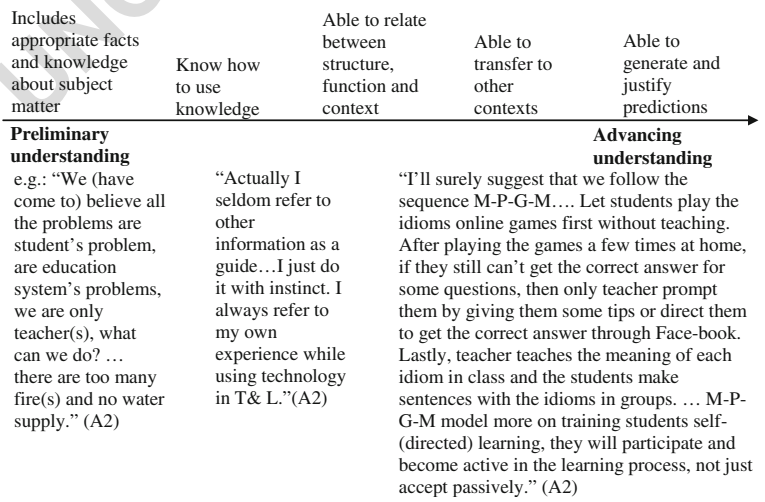

Fig. 3 Indicators of understanding: Coding for advancing understanding

> *Sometimes we have 6 to 7 period(s) of lesson to teach in a day. We have around 40 students in a class… Sometimes we can't afford to face the students' problems because we have to teach over 200 students in one day. … I have 250 students in my 7 classes I teach, and sometimes I have to face all of them in one day.* (Socialization—sharing experiences; A1, reflections)

Clearly, A1's feelings were not unique to her. A2 also shared a sense of helplessness shared by her peers in general, and more specifically, her group members:

> *I do not know where to start because (there are) too many challenges and problems (faced by) Chinese Language teachers. Same problems (are) always discuss(ed) among us and there's no solution… we really feel helpless and powerless. We (have come to) believe all the problems are student's problem, are education system's problems, we are only teacher(s), what can we do? … there are too many fire(s) and no water supply.* (Socialization—sharing emotions; A2, reflections)

This basic ethos was expressed in classroom discussions, in group discussions and in individual reflections. In sharing their feelings, emotions and experiences, these socialization exchanges created a sense of mutuality. This created a basis for the development of trust, care and commitment, which are critical *ba* characteristics. These two representative quotes also reflect the presence of other *ba* characteristics: fluctuation and chaos ("we can't afford to face students' problems," "there are too many problems and challenges," and "do not know where to start") and requisite variety ("same problems always discussed among us"). These conditions created opportunities for deeper reflections and externalizations as they began to deconstruct and reconstruct the problem at hand.

However, defining a problem requires looking beyond the surface symptoms. The instructor asked questions—particularly questions designed to push the discussion deeper towards the root cause. If an individual said that their students were not motivated, then one has to ask why they were not motivated. If the reason for this lack of motivation was because the subject matter seems completely irrelevant, then one has to ask why it comes across that way to the students. Group A's exploration led them down different paths; including paths that remained tacit earlier e.g., they started to look at their own practices as part of the puzzle. This matter-a-fact asynchronous exchange on GoogleWave exemplifies the increasingly open externalizations:

> *Aug 6, 9.05 am.A1: Do you think that teacher's teaching skills or pedagogy is also the root cause?*
> *Aug 6, 1012 pm. A2: Yes, I agree with you. If we can make T&L interesting, they will have motivation.* (Externalization—agreement; online group discussion)

Since the particular problem was situated in A3's context, the above seemed very much directed to A3. A3 could have responded negatively in this sensitive "face saving" culture, but instead this eventually led A3 to evaluate his own practice. He wrote about it in his online reflections on August 24, some 18 days after the exchange above, and began to consider if his approach to teaching and learning was part of the problem.

> *I always think I know the problem of my students … but now I start thinking, am I (part of the problem too)? … I always believed that I (have) enough experience in teaching… (but) the more I learn, the more I am afraid my personal ego has mislead me…* (Internalization—evaluative reflections; A3)

This data set also suggests a continuing development of trust, allowing conditions for difficult but candid discussions and reflections. At the same time, they also began to work

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towards a more defined understanding of their problem. Here, in an online asynchronous discussion, the exchanges moved the group towards clearer definitions about the parameters and goals of the problem:

> *Aug 11, 643 pm. A2: … (our) plan mentions that 40 % of the students can write essays and 60 % of the students cannot write essay, may I know the meaning of "cannot write essay"? Do u mean that they totally can't write a single word? or they make a lot of mistakes in the essay? Or digress from subject? … The plan also mention about "good essay". I think the word "good" is quite subjective, maybe we have to put in footnote for that to avoid misunderstanding, and to set up a very clear direction or concept.* (Externalization—evaluative dialogue)
>
> *Aug 12, 11.27 pm. (interjection as allowed by GoogleWave) A3: all the students that we group (in) "Cannot write essay" (have) marks below 20 to 40 %… what is your suggestion about the "good", may be you have (a) better word?* (Externalization—clarification dialogue)
>
> *Aug 12, 11.38 am.A1: "good" means that they cannot write essay that we want them to do, a full passage, without making many mistakes and so on. The 60 % students can write essays. Forty percent of may be cannot write a whole passage. Some making mistakes, some digress from subject and so on.* (Externalization—clarification dialogue)

In the meantime, another *ba* characteristic—autonomy—also began to show. They began to informally experiment with PowerPoint, and later Facebook and online games. These are indicators of a developing sense of autonomy i.e., taking responsibility for their own learning.

At this point, it is also worth noting that A1's reflection on August 24 demonstrated a naïve technological pedagogical and content knowledge, in that technology usage is taught to be in it of itself able to transform the quality of teaching and learning.

> *These 3 weeks, I try PowerPoint to teach students…I thought I am using technology. But I realize that the teachers like me are still repeating the same way of teach(ing)….just (that) the teaching material change from picture to computer…* (Internalization—action and reflection; A1)

It revealed an important realization by A1—different technologies with the same pedagogy will often yield the same result.

Such evaluative reflections before, during and after different actions took place frequently, often leading to more effective problem solving which allowed for opportunities to develop deepening understanding. For example, they began to look at different ways to get at the root cause of the problem. Here's an asynchronous exchange that took place on GoogleWave:

> *Aug 9, 7.36 pm.A1: B1 (from another group) had given me the website: Determine the Root Cause: 5 whys. You search and see how we can use this problem solving technique to identify our roots.*
>
> *Aug 9, 7.54 am.A2: Thank(s) A1 & A3… (I have) already read the article (on the website). I'll try to apply….* (Combination—drawing from multiple sources; online group discussion)

This sourcing of information from different knowledge bases (from B1 who discussed it in class; and from a website) highlights another emerging *ba* characteristic—redundancy. There were numerous ambient information sources—accentuating the availability of

multiple knowledge sources, but also highlighting the need to be discriminating of what can and cannot be used for the situation.

Equipped with this "5 whys" approach, they began to use it in combination with mind maps. Through a series of evaluation as highlighted in A2's reflections, they began to reframe the problem.

> *This week we started to discuss in gwave by listing out problems students may face … At first, it is quite confusing because we created too many (mind map) bubbles, and we don't know how to continue our discussion. After reading 5-whys approach, we decided to take out some bubbles that we can't do anything such as students' background. Then we try to ask 'why' for the remaining bubbles.* (Externalization and combination; A2, Aug 14 reflections)

These discussions and reflections began to take them down a very different trajectory from when they first started—maybe the students have a negative attitude (e.g. lazy, unengaged) because they really do have a hard time writing essays in Chinese; or, maybe they are afraid or frustrated to write because they don't quite have the vocabulary or grammar to write proper sentences and paragraphs. After receiving feedback during class discussions, they decided to collect more concrete data so that they can better define and understand the problem. A3 asked his students to write an essay, and then they analyzed the 33 essays they received. The following was one of the major conclusions the group made, as reported in their e-book:

> *Findings show that 90.61 % of the error (are) vocabulary errors (46 % from typo) [the Chinese character is written wrongly or is incomplete], 31 % from misuse of words [*e.g.*, wrong character but the right sound] and 13 % from missing words [*e.g.*, just didn't know how to write the character]).* (Combination; Group's e-book)

With the problem reframed and more defined, the group began to move to the next phase of exploring different ways to help students improve their vocabulary. There were indicators of emerging*ba* characteristics of autonomy, fluctuation and creative chaos, redundancy, requisite variety, and trust and commitment that paved the way for socialization, externalization, combination and internalization activities.

Advancing understanding in the process of exploring and acting on solutions

This phase began with the group setting more focused goals. Their externalizing discussions led them to a number of short-term and long-terms goals. One of the short-term goals was to help students "be able to correct at least 60 % of the vocabulary error." Note that vocabulary errors formed 90 % of all errors. They designed a collaborative activity on Facebook, so students can discuss and detect language errors on everyday things such as posters, sign boards and advertisements.

The implementation led to some success, but their explanations for why they did it were rather superficial, suggesting that Bereiter's "dumb luck" statement was in play here. For example, they merely explained that they chose to do it on Facebook because all the students were already regular users and they thought that it would motivate them by simply moving to this new setting. Their pedagogical reasoning did not suggest a deepening understanding. While they did use the TPACK framework to help guide their thinking, much of the ideas came from existing sources—largely their own experience and past practices. Note A2 and A1's September 21 and 22 reflections respectively:

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A2: Actually I seldom refer to other information as a guide…I just do it with instinct. I always refer to my own experience while using technology in T& L.
A1: Actually when we design(ed) the first activity… we just based on our experience and old pedagogy to design it….

Two key points to note here: firstly, much of their first solution was instinctive and based on past experience and behavior. Secondly, as part of the problem-based learning approach, they also had to evaluate and externalize their group's learning issues or knowledge gaps. As a result they started discussing the need for multiple sources to help guide their thinking. They began to retroactively make connections reported by scholars and expert practitioners. For example, they began to realize that the collaborative work they designed is related to Vygotsky's work on zone of proximal development and more knowledgeable other. In their reflections and e-book, they wrote about peer discussions and how students can learn from each other. In the e-book, they wrote that through this initial activity, their students can become more "aware of vocabulary errors in daily life," while citing related works of a Chinese language scholar.

It was not clear at this point if the retroactive connections they were making were indicative of deepening understanding. However, their subsequent solutions were more deliberate and reasoned—suggesting an advancing understanding. In designing the second activity, the group engaged in a more intentional and active combination and internalization process. This reflection on September 29by A2 shows how the group utilized theory and research-based practice to re-synthesize and design their solutions:

> *Before I know about TPACK-GPM, I just "design" my lesson by instinct. .... GPM (giving-prompting-making) open my mind by giving some suggestions about activities so that I can make my lessons more diverse (in nature). For example, the second activity our group propose—Idioms online games, at first we thought that GPM model only can be use in one way (in one sequential order)… but (there)after I know it can be used in other way(s)…I'll surely suggest that we follow the sequence M-P-G-M…. Let students play the idioms online games first without teaching. After playing the games a few times at home, if they still can't get the correct answer for some questions, then only teacher prompt them by giving them some tips or direct them to get the correct answer through Facebook. Lastly, teacher teaches the meaning of each idiom in class and the students make sentences with the idioms in groups. ... M-P-G-M model more on training students self (directed) learning, they will participate and become active in the learning process, not just accept passively.* (Dynamic interaction between externalization, combination, internalization; A2)

Quite autonomously, they began to think about the different broad pedagogical approaches—giving, prompting and making (terms derived from Hammond and Manfra 2009)—in relation to how technology can be used. But this time, they wanted to help students develop more self-directed and active learning habits. To do this, they first introduced online games to the students via Facebook so that the students can construct or "make" solutions as they tried to solve Chinese idiom puzzles. Then "prompting" by the teacher as well as fellow students would occur during Facebook discussions. This is followed by face-to-face direct instruction or "giving" to ensure that students had developed a proper understanding. And finally, students work in groups to "make" sentences with the different idioms, which were then shared with the whole class.

They went on to design and develop two activities based on this more deliberate approach. The group started to identify and use theory and research-based practices to design these activities instead of merely using them to retroactively justify the design of the activities. They

began to write and talk (externalize) with clearer and more cohesive patterns of explanations. They used multiple knowledge bases (combination) including theory and research-based practice to guide the design of their teaching and learning activities. And finally, in the instances discussed above, they were able to engage in evaluative reflections before, during and after action (internalization). All these suggest a progress towards knowledge creation and deepening understanding.

Look back and learn

After designing and running three activities over a 2-month period, the group carried out a post-test to gauge if vocabulary-related errors in essay writing had been reduced. The results were encouraging. For example, missing words in mid-sentence and misuse of words reduced significantly. Inaccurate or incomplete words were still numerous, but lesser than in the pre-test.

A1 was pleasantly surprised by the progress the students were making, and discussed candidly about the main reason for this change. In her reflections, she wrote that A3's approach and style of teaching changed to be in line with the design of the activities, and for the implementations thereafter.

> *The main reason our intended learning outcomes were achieved was the changes of teacher's teaching. The activities that we had planned, and implemented changed the style of teacher's teaching… we are no longer limited and dependent (on just the) textbook or workbook. We have also improved students' self-(directed) learning ability. … Teaching students how to fish is better than feeding them. Students have to learn how to "make" by themselves, and not just waiting for teacher's "giving".* (Internalization—action and reflection; A1)

By A1's estimation, A3 was using mostly the "giving" or direct instruction approach prior to their project, and by the end of their project, A3 was mostly using the "prompting" and "making" approach. Recall that at the beginning, A3 had become concerned that his "personal ego" had gotten in the way of effective teaching and learning. Note also that as A3 changed his way of teaching, the group seems to have also experienced a kind of liberation and empowerment when A1wrote "we are no longer dependent (on) textbooks or workbooks." In a way, deepening understanding is perhaps best demonstrated by actual changes in behavior and thinking.

A1 and A2 also reflected about helping the students to become more self directed learners, and be less dependent on the textbook or the teacher. There was also a growing understanding that pedagogical approaches can directly affect the way students learn. For example, in the two extracted quotes above, A1 and A2 wrote that the "making" and "prompting" approach is better suited to help students become more independent learners. "Teaching students how to fish is better than feeding them. Students have to learn how to 'make' by themselves, and not just waiting for teacher's 'giving,'" A1 wrote in her reflections.

Their understanding of how to use technology to increase teaching and learning quality was also quite visible. Consider this reflection by A1:

> *Not all technology tools (and) materials on the Internet (is) suitable for teaching… We must choose the suitable ones, like the activity we (did) last week, after we posted the video clip (on Facebook) about "filial piety" (and discussions and writing activities on Facebook), and we asked students to write about it, we also posted related materials (a Chinese filial piety story) and even mp3 music about "filial piety"…*

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Recall that this is also the same A1 who thought that technology in itself could transform learning. Her technological pedagogical and content knowledge had made significant advancements.

Summary

How did the knowledge creating activities play out in a way that help advance understanding and develop TPACK? Table 4 highlights some of the key dynamics with an accompanying elaboration below.

In the "Identifying problem" phase of PBL, socialization was essential so that sharing of experiences, emotions or mental models can take place. These sharing created a common language or understanding to paving the way for externalization. The *ba* qualities, which were most prominent here was a sense of mutuality that created the initial foundation on which trust and commitment could be built on. Because the problem was authentic and brought in from the learners' own context, the learning environment had the richness or the requisite variety that mirrored the real world. The problem also had a wicked nature. So, in this sense, the participants are effectively learning to integrate technologies in teaching and learning in a setting involving the expectedly complex interaction of multiple factors including context, pedagogy, technology and the content area. This in turn creates a problem and context that can be chaotic and in flux, but through instructional scaffoldings consistent with PBL allows for the learners to organize their sense-making process. When learners realized that they have common problems and challenges, it provides the initial foundation for the building of trust and commitment. It is worth noting that the initial socialization took place mostly in a face-to-face class setting.

In the "Defining the problem" phase, externalization was essential to enable articulation and negotiation of needs, terms, ideas and concepts. While socialization was more casual in nature, externalization activities began to take on more definition and verification of claims, and this in turn set the stage for combination activities. The process of combination was most active when they started drawing on each others' ideas and experiences, and expanded further when they began to draw on other knowledge sources such as primary data from closer assessment of students' work, articles and scholarly literature. As these data emerged, the redundancy of growing information and chaos of their problem setting compelled the participants to reframe the problem and reprioritize the information they had. In essence, the learning conditions allowed the participants to deconstruct and reconstruct their understanding of the wicked problem they were dealing with, and thus increasing the possibility of breaking down old mental models and routine behaviors to make way for new ones. Some of the externalization processes were triggered during in-class discussions, but much of the advancing externalization and combination activities took place primarily in online group discussions and the writing of the e-book assignment.

In the "Exploring solutions" phase, externalization continued to be active but participants were again compelled to engage in more intense combination. The participants began to exhibit greater autonomous behavior as they sought to design the best solutions possible. Building on their experience, conceptual frameworks discussed in class such as TPACK and GPM, ideas from other groups, their primary research data as well as other scholarly articles, they began to evaluate and synthesize the basic ideas for their solution. They eventually had to plan it with enough detail so that they could: a) defend their approach in class; b) implement their solution; and, c) report their implementation and experiences in the e-book. These were done mostly in online discussions and in the e-book, which formed the foundation for the next phase.

t4.1 **Table 4** The SECI, *Ba* and PBLframework and highlights of what transpired

t4.2 Problem-based Learning (PBL)	Socialization, Externalization, Combination & Internalization (SECI) [7]	Shared context (*Ba*)[7]
t4.3 *Phases and key characteristics are identified below.* *Purpose: To provide general direction for learners and drive understanding*	*S, E, C and I is/are dominant in certain PBL phases but is not exclusively so, nor is it always sequential.* *Purpose: Processes to drive knowledge creation activities*	*Conditions: Autonomy, fluctuation and creative chaos, redundancy, requisite variety, trust and commitment* *Purpose: To create enabling conditions to energize knowledge creating processes (SECI)*
t4.4 **I**: Identifying problem[1] • *Presented with the problem*[2] • *Problem has a wicked nature* [3 & 4] • *Problems come directly from participants' real life teaching and learning context* • *Preferably faced by at least two other persons in class who are willing to take ownership of the problem*	*Socialization* was critical in this phase as sharing of relevant *experiences, emotions and mental models* can pave the way for deeper externalization. e.g. 1: "I have 250 students in my 7 classes I teach, and sometimes I have to face all of them in one day." (A1); e.g. 2: "we are only teacher(s), what can we do? … there are too many fire(s) and no water supply." (A2). *Ba qualities: Requisite variety*—because the problem was derived from the real world, the internal diversity of the learning environment matched the diversity of the external environment. As a result, *fluctuation* was also present. The *sense of mutuality* also provided an initial foundation for the building of *trust* and *commitment*. *Supporting medium:* Face-to-face open discussions and online reflections	
t4.5 D: Defining the problem[1] • *Analyze and frame the problem by identifying and verifying relevant facts*[2] *Hard scaffoldings such as Know-Need-Do table, TPACK*[5]*& GPM*[6] *are introduced to aid in the discussion, problem analysis and framing process*	*Externalization* was critical here to enable articulation and negotiation of needs, terms, ideas or concepts. e.g.: "… (our) plan mentions that 40 % of the students can write essays and 60 % of the students cannot write essay, may I know the meaning of "cannot write essay"?" (A2). *Combination* also emerged here as participants began to draw on multiple knowledge bases and broke down concepts into meaningful parts.e.g. "Findings show that 90.61 % of the error (are) vocabulary errors, 31 % from misuse of words and 13 % from missing words. (Group's e-book). *Ba qualities: Redundacy*—lots of possible knowledge sources, but also highlighting the need to be discriminating of what can and cannot be used for the situation. Continuing fluctuation and chaos. *Supporting medium:* Online discussions, e-book.	
t4.6 E: Exploring solutions & opportunities[1] • *Generate hypotheses about possible solutions*[2] *Knowledge gaps are identified for further self-directed research*[2]	*Externalization*—see above. e.g.: "…Before I know about TPACK-GPM, I just "design" my lesson by instinct. …. GPM (giving-prompting-making) open my mind by giving some suggestions about activities so that I can make my lessons more diverse (in nature). For example, the second activity our group propose." (A2). *Combination*.e.g. "M-P-G-M model more on training students self-(directed) learning, they will participate and become active in the learning process, not just accept passively." (A1). *Ba qualities:* While other conditions such as redundancy are in play, *autonomy* is needed here so the participants will pursue the best solution possible. *Supporting medium:* Online discussions, e-book.	
t4.7 A: Acting on best possible solutions[1] • *Learners apply their new knowledge and evaluate their hypotheses in light of emerging data and new knowledge* [2] • *Phases between phases D, E, and A can be iterative in nature*	*Internalization* occurred through action and reflection before, during or after practice in light of emerging data and new knowledge. e.g. "The activities that we had planned, and implemented changed the style of teacher's teaching… we are no longer limited and dependent (on the) text book or workbook. We have also improved students' self-(directed) learning ability. … Students have to learn how to 'make' by themselves, and not just wait for teacher's 'giving.'" (A2) *Ba qualities: Autonomy* is essential so that actions are personally intentional rather than instructed; *requisite variety* allows real actions to have real	

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t4.8 **Table 4** (continued)

Problem-based Learning (PBL)	Socialization, Externalization, Combination & Internalization (SECI) [7]	Shared context (*Ba*)[7]
	consequences. *Supporting medium:* Real context, online reflections/ discussions, e-book.	
t4.8 L: Looking back and learn[1] *Learners reflect on the knowledge gained*[2]	*Internalization* wasin play here through reflection during and after action. e.g."Not all technology tools (and) materials on the internet (is) suitable for teaching… We must choose the suitable ones, like the activity we (did) last week…" (A1). *Supporting medium:* Online reflections and face to face discussions.	

Key references: [1] Bransford and Stein 1993; [2] Hmelo-Silver 2004; [3] Rittel and Webber 1973; [4] Tee and Karney 2010; [5] Mishra and Koehler 2006; [6] Hammond and Manfra 2009; [7] Nonaka et al. 2001

In the "Acting on the best possible solutions" phase, the participants enacted their understandings and ideas, and thus created a fertile platform for internalization activities. Internalization occurred through these actions as well as reflections before, during and after the implementation of their solution. Here, their mental models began to change as reflected by their changing understanding of what teaching with technology can mean as their enacted teaching style also began to evolve. The key supporting medium here is obviously the real context where the participants can enact their emerging understandings, but the activities revolving around the online discussions and reflections, as well as the e-book allowed for reflections before, during and after the implementation of their solution.

In the final phase, "Look back and learn," internalization was the most prominent here as participants were asked to reflect about their thinking and their actions. The key supporting mediums were online reflections and face-to-face discussions.

Conclusion

The findings of this study suggest that a problem-based learning approach designed together with a conducive *ba* to stimulate socialization, externalization, combination and internalization can help teachers deepen their understanding in the context of TPACK. The in-service teachers demonstrated a more nuanced understanding of the complex interplay between the three basic components of knowledge—content, pedagogy and technology (Koehler and Mishra 2005). They started with simplistic views of how technology itself can transform learning, but over time, began to demonstrate progressing knowledge and understanding of using pedagogical methods and technologies in ways that give the students the best opportunities to achieve the intended learning outcomes.

Three major implications can be concluded in this study, and discussed here:

Firstly, the framework illustrated in Fig. 1 and what transpired as summarized in Table 4 can be developed further as a guide to design the necessary conditions (*ba*) to stimulate knowledge creating processes (socialization, externalization, combination and internalization) that are grounded on developing real understanding. The purposeful use of problem-based learning approach seems to provide the necessary heuristics to drive towards understanding, rather than just relying on serendipitous imitation or trial and error. This presents at least a set of evidence to address the concerns raised by Bereiter (2002) that Nonaka's model does not quite address the issue of understanding.

It also builds on previous studies (Tee and Karney 2010; Tee and Lee 2011) that have found Nonaka's model to be a promising basis for the design of learning activities and learning environments. In order for these findings to be extrapolated further, similar studies need to be done in different types of contexts involving different demographics. Subsequent studies may also consider the use of different data collection techniques such as in-depth interviews and stimulated recall to get a clearer picture of students' thinking during class or group discussions. Such studies can also begin to reveal how knowledge is socially constructed, specifically how facilitation can be done to enhance discussions for deeper understanding (e.g. Tan and Tee 2012).

The second implication will be discussed from the angle of SECI and ba. Further studies need to be done to concentrate on describing SECI and ba with greater specificity. For example major questions may revolve around these issues: Are some forms of socialization (or externalization, combination and internalization) more constructive than others for the purposes of knowledge creation and advancement of understanding? What and how do scaffoldings work most effectively under certain ba conditions, such as autonomy, requisite variety and redundancy? Answering these questions will continue to test the overall framework and sharpen the specificity of the details.

The final implication will be discussed from a PBL angle. The PBL phases have well-defined steps, but don't quite spell out the ethos and the nature of dialogue that needs to take place. SECI and ba can play that role. For example, through socialization processes, the importance of sharing feelings, experiences and mental models particularly early in the PBL phases should be emphasized. Further research can delve into questions such as: When socialization breaks down, do other forms of knowledge creation dialogue and activities also break down? Another example is to create *ba*-like qualities in PBL settings by design, and cultivating aspects such as redundancy and requisite variety to maximize the potential of the learning opportunities. In other words, the creation of *ba*-like ethos can add important details to describe the PBL environment.

Ultimately, this study provides a beginning point to further study the usefulness of SECI, Ba and PBL in designing learning activities and environments.

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