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Fostering design-oriented collective reflection among preservice teachers through principle-based knowledge building activities

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ABSTRACT

Teacher's reflective capacity is an important means for teachers' growth in professionalism. This design-based research investigated the effects of knowledge building (KB) principles on pre-service teachers' reflective capacity in two intervention cycles. Particularly, the two principles of "community knowledge, collective responsibility" and "symmetric knowledge advancement" were highlighted. Participants include 25 pre-service teachers who practiced their micro-teaching during two intervention cycles. Data include: (1) records of online activities; (2) content of online feedback in the form of lesson design ideas; and (3) two open-ended surveys. Findings based on the first intervention cycle revealed that guided by the first KB principle, the participants were able to progressively work more cohesively as an online collaborative community, and extend their reflective concerns about teaching to learning. However, there was no significant improvement in terms of the quality of feed-backed lesson design ideas. To address this issue, the second principle was added in the second design cycle. Moreover, using survey as a reflection tool, an attempt to extend the investigation from pre-service teachers' reflection on teaching concerns to reflection on technological, pedagogical, and content knowledge (TPACK) was taken into consideration in the second intervention iteration. As a result, the quality of the feed-backed lesson design ideas was significantly improved, indicating a sign of pre-service teachers' enhanced design fluency. In addition, the participants' design knowledge was also improved as evidenced in their deepening their reflection from basic, to more integrated, TPACK knowledge. Implications regarding principle-based, design-oriented knowledge building activities to foster reflective thinking for teacher preparation are discussed.

1. Introduction

Although developing pre-service teachers' reflective thinking capacity is a challenging task, its importance is well documented (Gelfuso & Dennis, 2014; Kimmons, Miller, Amador, Desjardins, & Hall, 2015; Pedro, 2005; Schon, 1983). Unfortunately, conventional approaches to teacher preparation tend to focus more on helping prospective teachers accumulate and master curriculum-based, exemplary teaching knowledge and skills for direct instruction (Adams & Engelmann, 1996; Hollingsworth & Ybarra, 2017). Relatively less attention is being paid to the development of reflective thinking skills for pre-service teachers to practice creative teaching that is required in today's classrooms (Jordan, 2016; Saywer, 2004). Reflection is critical for preparing creative teachers who

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will not settle for merely learning from model teaching practice (McAlpine & Weston, 2000), but will also aim for going beyond best teaching practice. To this end, they need to practice their teaching not just according to pre-defined instructional procedures, but in a less structured and more adventurous fashion (Cohen, 1989; Hong & Chai, 2017). This includes producing creative lesson design ideas, and then continuously improving these ideas. Such adventure-oriented teaching practice will better prepare future teachers who are more likely to address diverse learner needs and individual differences, and consequently help learners to become effective knowledge workers for a knowledge-intensive society. This study aims to address a gap in current teacher reflection literature through the connection of teachers' reflection and teachers' collective knowledge creation.

1.1. Reflection for teaching practice

Building on an industrial-age model of education, an important educational goal for teacher preparation is to develop effective teachers who can efficiently meet curricular requirements that define core teaching knowledge and skills. To this end, pre-service teachers are guided to directly observe and learn from experienced teachers whose teaching performance is regarded as effective or best practices as they are able to transmit difficult concepts in the shortest available time (Reeves, 2009; Stone, 2002). However, while emulating best teaching practice is desirable, building teachers' capacity to go beyond "best teaching practice" is key to innovate the profession. To this end, training prospective teachers to master direct instruction is not enough. It is also important to launch prospective teachers on a professional development trajectory that would enable sustained improvement in their teaching practice. To this end, they need to be equipped with strong reflective capacity and develop a more innovative and adaptive aptitude (Chen, Kang, & Leou, 2010).

Through reflection on one's own strengths and weaknesses in teaching practices, a teacher can better understand the potentials and limitations of his or her teaching (Hong, Zhang, Teo, & Scardamalia, 2009; Guskey, 1988). Current pre-service teacher preparation programs in Taiwan, however, tend to focus on efficiency in pre-service teachers' acquisition of essential content knowledge and teaching skills through repeated drill and practice. Such repeated practice for mastery does not require much of one's reflective capacity for teaching improvement (Yang & Huang, 2016). As a result, the reflective disposition and mindset could be underdeveloped in teacher preparation courses. It is thus necessary to rethink how to transform the efficiency-mode of teacher preparation into critical and reflective approaches that help future teachers to develop adaptive mindsets for more creative teaching practices (Radloff & Guzey, 2017; Rusche & Jason, 2011; Schon, 1983).

One way to make reflection effective is perhaps to transcend reflection as merely individual or intrapersonal activities (Darling-Hammond & Bransford, 2005). Building on a sociocultural framework, reflection should not just be viewed as individual activities, but it should also be deliberately designed to become a collaborative community activity (Lin, Hmelo, Kinzer, & Secules, 1999; Harford & MacRuairc, 2008; Hong & Scardamalia, 2014). Moreover, building on Popper's (1987) 3-world epistemological framework (Boyd, 2016), reflection should not be just focused on personal thoughts that exist only privately in human's mind that Popper refers to as the 2nd world. Reflection should instead be focused on ideas that exist in public spaces, e.g., an online discussion forum (Popper referred to as the 3rd world). Ideas in the 3rd world can thus be collectively critiqued and improved. Being able to genuinely learn to teach together as a collaborative community, however, is a great challenge. To enable a community like this would require collective reflection, by treating other community members as esteemed collaborators and valuing their critical feedback or ideas in order to attain a deeper understanding that would not be attainable by one person alone (Nissilä, 2005). As also argued by Wilson and Dunn (2004), to better achieve self-understanding, one should go beyond mere reflection on oneself and transform reflection into a socially interactive activity. Lin et al. (1999) propose a contrasting approach that enables social or collective reflection by comparing one's perspectives with peers' or experts' perspectives. The contrast acts to facilitate deeper reflection on one's strengths and weaknesses (Foong, Nor, & Nolan, 2018; Gick & Paterson, 1992). Other scholars also suggest that it is possible to facilitate social reflection by using collaborative feedback from others to facilitate the reflective development of one's teaching practices (Brandt, 2008; Hattie & Timperley, 2007; Jones & Gallen, 2016). How to capitalize on such collaborative feedback for deeper reflection, however, remains a pedagogical challenge. However, it is posited that with innovatively designed guidance to enable collaborative feedback from peers, diverse teaching ideas and perspectives can be made accessible, and thus can be used as a contrasting catalyst to foster in-depth teaching reflection. To transcend reflection as intrapersonal activity to reflection as a social activity, technology-supported environments have been developed to facilitate collaborative reflection and peer feedback (Rodríguez-Triana et al., 2017). For example, videos have been used in teacher learning environments to allow peer teachers to observe and model how other more experienced teachers performed their teaching practices (Fadde, Aud, & Gilbert, 2009; Stockero, 2008). Moreover, many technology-enhanced learning environments have also been widely used to facilitate collaborative reflection using feedback (Schwartz, Lin, Brophy, & Bransford, 1999; Xie, Ke, & Sharma, 2008). Nonetheless, reflection may need to be anchored on specific aspects of teaching to provide foci. This is because pedagogical phenomenon is constituted in interactions between the teachers, learners, learning environment and the subject matter, which is complex in essence. To foster teachers' design expertise that is crucial for 21st century classroom (Koh, Chai, Hong and Tsai, 2015), we identify teacher concerns and teacher knowledge as two anchors for reflection.

1.2. Reflection on teacher concerns and teacher knowledge

Of all the foci of teacher reflection, perhaps teacher concern and teacher knowledge are most essential (Grossman, 1990; Hao & Lee, 2015; Mishra & Koehler, 2006; Mok, 2002; Poulou, 2007). From the perspective of design thinking (Kali, Goodyear, & Markauskaite, 2011; McKenney, Kali, Markauskaite, & Voogt, 2015), teaching concerns could serve as the starting point of teacher's design. Teacher concerns are manifestation of their *empathic* understanding of learners' learning difficulties. Teaching knowledge

then provide the epistemic lens to help teachers to *define* the pedagogical problem, which subsequently shapes the *ideation*, *implementation*, and *testing* of the teaching ideas and strategies.

Teacher concern has been frequently argued by teacher educators as a key factor in teacher effectiveness (Crawford, Chamblee, & Rowlett, 1998; Murray-Harvey, Slee, Lawson, Silins, Banfield, & Russell, 2000). According to Fuller (1974), there are three general types of teacher or teaching concern, including concern about self, concern about self as a teacher, and concern about learners. Previous studies indicate that novice teachers tend to be more concerned about self and self as a teacher (e.g., whether as a new teacher, I will appear too nervous in front of my students); in contrast, veteran teachers tend to be more concerned about learners (e.g., how to revise my instructional methods in order to enhance students' understanding) (Fuller, 1974; Kyriacou & Stephens, 1999). It is important to guide pre-service teachers to reflect on their personal teaching concern. The reflection should go beyond self-related concerns to include concerns related to the learners; and this represents an important pedagogical challenge for teacher educators. It would also be helpful to look into pre-service teachers' anticipated concern before teaching practice and their actual concern during teaching practice. There is likely to be a mental gap between their actual and anticipated teaching concern. Apparently, a more specific and systematic investigation regarding how pre-service teachers reflect on their teaching concern would inform teacher educators on how to increase the teachers' reflective capacity, and consequently, improve their teaching practices.

Teacher knowledge, on the other hand, constitutes the essence of the teacher education curriculum (Grossman, 1990; Shulman, 1987). Particularly, teachers need to be reflective on what they know and do not know about the subject area for effective teaching. More importantly, Mishra and Koehler (2006) have built on Shulman's (1987) pedagogical content knowledge (PCK) to propose a TPACK (i.e., technological, pedagogical, and content knowledge) framework to support effective teaching. Basically, TPACK can be divided into three basic forms of knowledge (i.e., technological, pedagogical, and content knowledge respectively), and another four types of more integrated knowledge including, technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and technological, pedagogical, content knowledge (TPCK). Previous studies indicate novice teachers are usually in the early stage of acquiring core teaching knowledge, so their reflection is less likely to focus on more sophisticated, integrated knowledge. For example, knowing how to craft authentic problems to situate collaborative content knowledge construction supported by technology requires integration of the notions of authentic learning, collaborative learning and the content knowledge construction supported by technology. Koh's (2013) analysis of preservice teachers' lesson design indicates that preservice teachers lack such competence. In contrast, experienced teachers can be more adaptive as they accumulate abundant case examples through teaching, and could thus synthesize different types of knowledge into a sophisticated form of knowledge for more creative teaching (such as possessing strong PCK of knowing how to use a certain teaching strategy to teach specific content). However, as Angeli and Valanides (2009) have highlighted, TPACK is transformative rather than cumulative. This implies that reflective accumulation of experience is less important than transforming reflection into new knowledge. Accordingly, it would be very important for researchers to look into how to help novice teachers to be reflective not merely on using basic forms of knowledge, but also on the innovative creation of integrated knowledge. Teacher education must design proper guidance to engage pre-service teachers in higher-level reflection on more integrated forms of knowledge. The challenge would thus be how to help pre-service teachers become more knowledge creation oriented reflective teachers.

1.3. Knowledge building activities

To address the above issues, this research employs the knowledge building pedagogy to help foster pre-service teachers' reflective capacity. As an innovative, constructivist-oriented pedagogy (Koschmann, 1996), knowledge building is defined as a collaborative process highlighting sustained generation and improvement of ideas (e.g., better lesson design ideas) valuable to a community (Scardamalia & Bereiter, 2006). Knowledge building pedagogy is principle-based, which distinguishes it from proceduralized, task-oriented, or ritualistic pedagogical approaches. The latter approaches value procedures, tasks, rituals, routines, or activities that are usually pre-defined based on some instructional manuals or scripts. Such approach is noticeable in current preservice teacher reflection literature (Harford & MacRuairc, 2008; Radloff & Guzey, 2017). One important pedagogical goal of such approaches is to help learners acquire and master knowledge and skills within a given time frame (cf. Sawyer, 2004; 2006). The positive effects of this pedagogical approach have been well documented in the literature (Adams & Engelmann, 1996; Harford & MacRuairc, 2008; Radloff & Guzey, 2017) and it has also been widely acknowledged to be useful for efficiently training the numbers of pre-service teachers needed in the education industry. However, the downside is that it does not encourage pre-service teachers to be reflective practitioners for adaptive and creative teaching that cannot be reduced to direct instruction (cf. Sawyer, 2004; 2006).

Contrary to the proceduralized pedagogical approach, knowledge building employs a set of principles as guiding heuristics for the teachers to facilitate the formation of a knowledge creation community. The community aims to foster epistemic agency through dialogic reflection and collective knowledge advancement (Scardamalia & Bereiter, 2006). Under this approach, reflective activity becomes a natural byproduct for pre-service teachers as they have to produce their initial lesson ideas and, through continuous reflection and dialogues in the community, improve the ideas over time. They are encouraged not to mimic exemplary teaching skills but to adapt their own teaching practice under different problem contexts. They are encouraged to view classroom issues as opportunities for progressive problem-solving (rather than problem elimination), and to solve progressively more difficult problems. They are thus equipped to generate better lesson ideas and solutions each time. The KB approach demonstrates for the pre-service teachers a pedagogical model that is not pre-determined and proceduralized. Instead, the pre-service teachers need to be engaged in reflective and continuous teaching innovation. To participate meaningfully in the KB principle-based practice, they are challenged to revise their conceptions of what teaching and learning means. Doing so requires the pre-service teachers to constantly innovate their own current best teaching practices by means of design, test, and re-design of various lesson ideas. Previous research has indicated

that such an approach can be effective in fostering more adaptive teaching among pre- and in-service teachers (Hong et al., 2009; Hong, Chen, Chai, & Chan, 2011). Yet, it is unclear if such an approach would also work for pre-service teachers.

To enable principle-based teaching innovation, Scardamalia (2002) has proposed 12 knowledge building principles as pedagogical heuristics for teachers. For example, the principle of 'idea diversity' states that "idea diversity is essential to the development of knowledge advancement, just as biodiversity is essential to the success of an ecosystem. To understand an idea is to understand the ideas that surround it, including those that stand in contrast to it. Idea diversity creates a rich environment for ideas to evolve into new and more refined forms" (Scardamalia & Bereiter, 2010, p. 79) (see Appendix 1 for a brief introduction of each principle). As guiding heuristics, knowledge-building principles are used to transform pre-service teachers into knowledge workers who engaged in various types of creative lesson design and teaching activities.

2. Present study

Previous knowledge building research indicates that principle-based knowledge-building pedagogy is useful for helping students in various subject areas such as science (e.g., Zhang, Scardamalia, Reeve, & Messina, 2009), mathematics (e.g., Moss & Beatty, 2010), and reading (e.g., Zhang & Sun, 2011). Relatively fewer knowledge-building studies were dedicated to investigating how pre-service teachers learn by assuming the role of knowledge workers (see Chen & Hong, 2016; for a review of recent knowledge building studies). Within these studies, some indicate that knowledge building is effective in transforming pre-service teachers' epistemological beliefs to be more student-centered (e.g., Chan & van Aalst, 2006; Hong et al., 2011, Hong, 2014; Laferrière, Lamon, & Chan, 2006; Van Aalst & Chan, 2007). Other studies suggested that knowledge building theory and pedagogy are helpful to teachers in improving their teaching practices (e.g., Hong et al., 2009; Hong & Lin, 2010). However, it remains unclear if knowledge building is directly helpful in promoting pre-service teachers' reflective capacity, with particular focus on teaching concerns and teaching knowledge. It is posited that with principle-based guidance, as compared with pre-defined teaching procedures, pre-service teachers would be more likely to work reflectively and creatively and form a more adaptive mental habit towards teaching problems and lesson design issues, therefore, enhancing their reflective thinking capacity.

2.1. Research questions

Under current educational context in Taiwan, most teacher education programs are still largely focusing on cultivating teacher's teaching competence to fulfill outcome-based education (Elliott, 2015), rather than focusing on transforming teachers into knowledge building practitioners (Chai, Koh, & Teo, 2018; Hong & Chai, 2017). The latter view of teaching requires teachers to work collectively to tap on distributed expertise and to build their design fluency through iterative design, enact and reflect cycles. Developing teachers' design capacity has been shown by international researchers that it is likely to lead to more innovative teaching and resolve barriers in reform (Makkia, O'Nealb, Cottena, & Rikard, 2018). As such, in the present research, we employed knowledge-building pedagogy–an innovative, principle-based approach–to engage teachers in knowledge building activities, with particular focus on two principles in two design cycles. The first principle is "community knowledge, collective responsibility." Specific to the context of teacher preparation, this principle highlights the importance for pre-service teachers to work as a professional community and to take collective responsibility to advance knowledge in the community. The second principle "symmetric knowledge advancement" highlights the value that contributing knowledge to help others is a way to gain knowledge. Namely, this is to encourage pre-service teachers to actively contribute ideas as feedback to their peers, which reciprocally would advance their collective knowledge work. The specific questions asked for both of the two design cycles in this study are as follows:

(1) How does engaging pre-service teachers in principle-based knowledge building activities help them work, interact, and collaborate as a community?
(2) Will they be able to help each other learn to teach more reflectively by progressively providing better (more explanation-oriented) teaching feedback/ideas?
(3) Will the use of survey as a reflection tool help them become better reflective practitioners?

This study is conducted within the Taiwan context and is concerned particularly with the mathematics subject because it is found from PISA reports (OECD, 2016) that although Taiwanese students scored high in mathematics performance, they also showed low motivation towards mathematics learning. As such, the educational reforms in Taiwan have started to request pre-service preparation institutions to pay more attention to adopt innovative pedagogy in order to better foster creative teachers who are more likely to innovate teaching and motivate mathematics learning in the future.

3. Methodology

This study aims to investigate whether engaging pre-service teachers in principle-based knowledge building activities to reciprocally provide teaching feedback for lesson design ideas to each other in a computer-supported collaborative environment, i.e., Knowledge Forum (KF), would enhance teachers' reflective capacity during their micro-teaching practice. To this end, KF serves as a shared design and reflective space for community members to engage in unfolding collective feedback activities. Particularly, it is expected that such idea-centered feedback and reflection would enhance their teaching concerns and teaching knowledge (as teaching concern represents a means to empathize with learners and teaching knowledge a means to further address teaching/

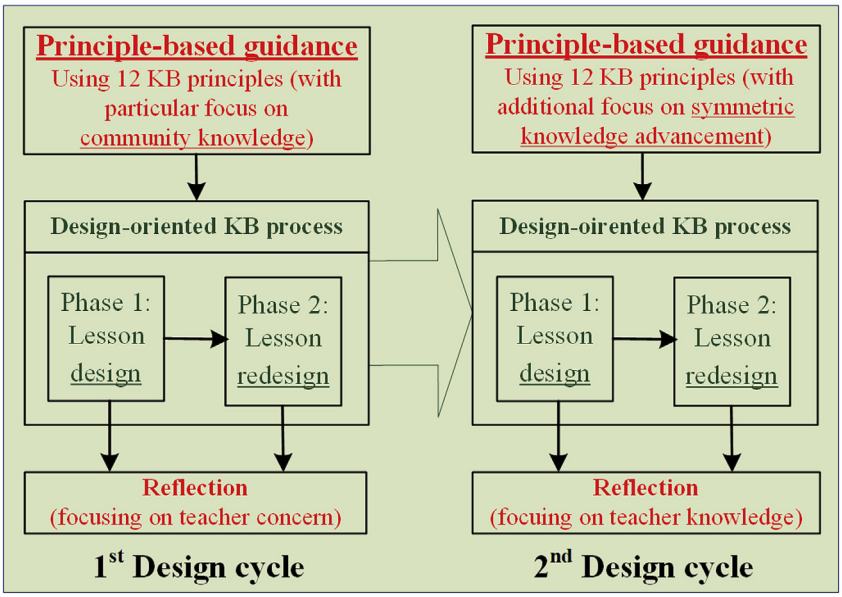

Fig. 1. Research design using design-based research (DBR) with two iterative design cycles.

learning issues). In the following we first elaborate the research design and then describe the implementation process of the two intervention cycles, along with the details about data sources and analysis.

3.1. Research design

This study employs design-based research (DBR) (Anderson & Shattuck, 2012). As an emerging research methodology in the field of learning sciences, DBR highlights the importance of using carefully designed interventions to address educational issues and problems. Accordingly, to conduct DBR means to iteratively test, adapt, and re-test the designed interventions in order to generate more effective solution frameworks for the problems at issue; as such, data analysis usually focuses on iterative comparisons (McKenney & Reeves, 2013). As the present study intends to test and adapt the use of an innovative knowledge building approach as a pedagogical intervention in order address a long-lasting issue concerning Taiwanese teacher-education, DBR appears to be a highly relevant method.

Using DBR, this study employs two design cycles (see Fig. 1) to investigate whether knowledge building principles (as interventions) would be able to guide pre-service teachers to engage in collaborative knowledge building as a community and to progressively become more able to provide quality feedback in the form of more explanation-oriented lesson design ideas to each other. The shared pedagogical goal of the two design cycles was to foster pre-service teachers' explanatory coherence and reflective activities. In this research, participants were preparing to become mathematics teachers in middle-school. All activities in the two design cycles were guided by a set of 12 knowledge building principles (see Appendix 1 for a brief description of all the principles), with, two of them especially emphasized: (1) the principle of “community knowledge, collective responsibility” for collective reflection in the first design cycle; and (2) “symmetric knowledge advancement” for improving feed-back lesson design idea quality in the second design cycle. Correspondingly, the three research questions are concerned with (1) principle-based knowledge building activities; (2) quality of lesson design and feedback process; and (3) participants’ reflective outcomes, in both design cycles.

3.2. Pedagogical approach

As Fig. 2 shows, the course (in Design cycle 1) was pedagogically designed to have two phases with each phase containing three parts: (1) Design: each participant needed to propose a lesson design in the beginning of a phase; (2) Teach: based on lesson design ideas, each participant takes turns to perform micro-teaching in class (which was fully videotaped for later review and feedback use), and (3) Reflect: after each teaching, other classmates then engaged in online feedback (by providing feedback ideas) in Knowledge Forum via collective reflection in the community; also, at the end of each of the two phases they completed a survey (as a reflection tool). Specifically, each participant's practice was guided by the following idea-centered knowledge-building processes (Hong & Sullivan, 2009; Scardamalia, 2002) (see the right part of Fig. 2): (1) idea-generation (to produce lesson design ideas); (2) idea-enactment (to practice micro-teaching based on initial ideas); (3) idea-diversification (to give or receive feedback/ideas from others for teaching improvement); and (4) idea-elaboration (to reflect on one's own initial lesson design and then to redesign for next practice in the following phase). It is posited that this collective idea-centered activities would increase the scope of collective reflection activity in the community and accordingly would also improve the explanatory quality of their feed-backed lesson design

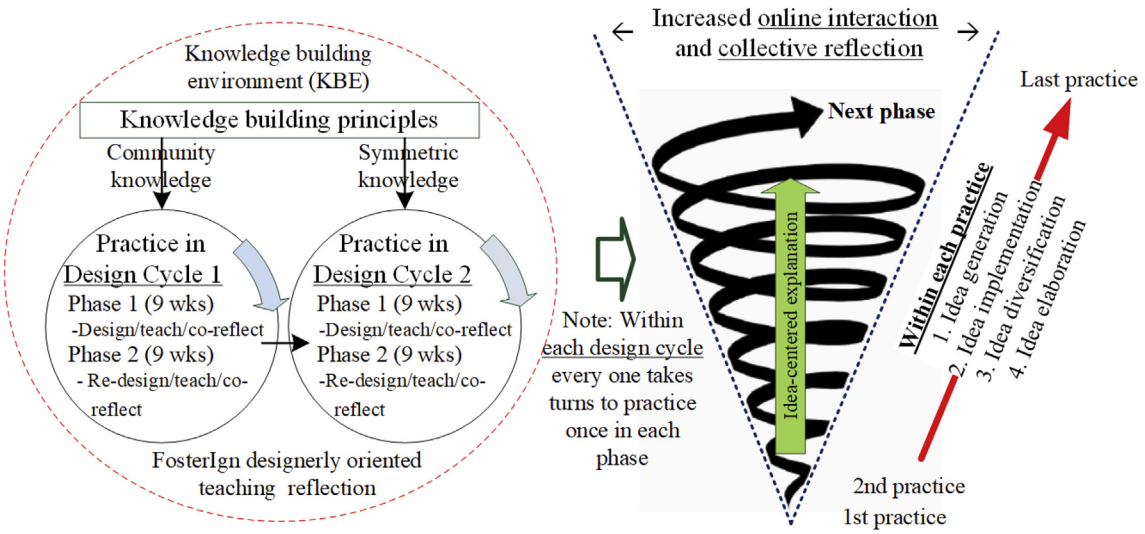

Fig. 2. Details about the two design cycles in this study.

ideas. Underlying the above idea-centered activities is a set of 12 knowledge building principles. In particular, the principle of "Community knowledge, Collective Responsibility" was particularly highlighted in the first design cycle. The participants were encouraged, and reminded at the beginning of each class, to work collectively as a professional community and to help one another learn to teach by giving relevant feedback ideas for improvement. Each of them was required to take turns to practice, by teaching in front of the rest of the class members. Then class members give ideas and feedback online in the Knowledge Forum platform. The collective community responsibility was to help all class members learn, reflect, and understand how to act better as a knowledge-building teacher. Effectively collaborating and communicating with others is an essential aspect of the community's collective responsibility. As there are two phases of (i.e. pre and post) micro-teaching (each lasting for 9 weeks), every student had a second chance to re-design and improve his or her lesson design and teaching practice through the same process of idea-generation, idea-implementation, idea-diversification, and idea-elaboration.

As for Design cycle 2, in the spirit of design-based research, it is meant to address pedagogical challenges emerged from Design cycle 1. Thus, an additional knowledge building principle was introduced in this iterative cycle (see below for more detailed explanation in Design Cycle 2).

The course instructor was an experienced practitioner in implementing knowledge building pedagogy. He served as a backseat driver and was responsible for the course design and related administrative matters. The instructor introduced idea-centered knowledge-building pedagogy/principles, and the Knowledge Forum (KF) functions, namely note contribution, note reading, and note building-on at the start of the course. Subsequently, to implement the principle-based knowledge building, there was no lecture or direct instruction from the instructor. Instead, before each practice, the instructor would guide the participants to engage in class activities that are congruent to the principle. The designated student needs to "contribute" her initial lesson design ideas by posting a note in KF before her turn of teaching practice; the other students then "read" the posted lesson design ideas before the teaching practice; and after the teaching practice, they comment on the teaching practice by "building-on" the initial lesson design ideas, which constitute the online feedback ideas. Then, the designated student can reflect on his or her teaching based on all the feedback. This completes a student's micro-teaching assignment and another designated student would then take charge and engage in the same practice cycle, until every student practice once. Then, the second phase would be implemented for them to re-design their lessons. In the following, we further elaborate participants, data source and analysis, and instrument in each of the two cycles.

4. Design cycle 1

4.1. Participants

Participants in this study were 16 preservice teachers from a teacher preparation program in a national university in Taiwan. They took a middle-school Mathematics micro-teaching practice course during internship (which is required after completing most theory-oriented courses such as educational psychology) for an 18-week semester. The preservice teachers have taken some courses together before the intervention. Most of them knew each other well and felt comfortable to give constructive criticism. The course was supported by Knowledge Forum–an online collaborative knowledge building environment. As this is a practice-oriented course, each student was required to take turns to perform teaching during two phases of micro-teaching in class with other classmates serving as audience. After this course, they would be allowed to practice their teaching in a real classroom context with middle-school students. The present study focuses on the micro-teaching part.

4.2. Data source and analysis

Data sources included (1) online activity logs in Knowledge Forum, (2) online feedback/ideas, and (3) a survey (used as a tool for reflection on teacher concerns). Regarding analysis, first, an analytic toolkit (built-in in KF) was used to gather online activity records for descriptive statistics. Second, for online feedback/ideas, Dempsy, Driscoll, and Swindell's (1993) original coding framework was adapted into two general types of feedback/ideas: procedure-oriented and explanation-oriented. Procedure-oriented feedback/ideas are ideas focused on helping practitioners to correct and modify teaching procedures that may not transmit the knowledge efficiently enough from a knowledge telling perspective. An example of a procedure-oriented feedback/ideas from a student is: "*The example you provide [during your teaching practice] to students in class should be based on correct information. During your lecture, your attention has been fixed on one particular area for a long time. You should have more eye contact with the rest of the students.*" In contrast, from an idea-centered knowledge building perspective, the goal of teaching practice is to go beyond one's current best practice. So it is more important to provide explanation-oriented feedback/ideas to help the designated practicing teacher to further improve his or her lesson design ideas for the next design of teaching practice. For example, a student provided a feedback/idea pointing to better practice with a sensible reason: "… *you invited a student to solve a problem on the whiteboard. But you did not ask her to explain how she solved problem. I think it is better to ask her to explain her thoughts because other students may have different thoughts about how to solve this problem which may be very different*." To analyze this set of data, content analysis was employed by using an open coding approach (Strauss & Corbin, 1990). The two coded themes were firstly quantified by counting the number of instances of each theme and then analyzed by further inferential statistics.

4.3. Instrument

Regarding the open-ended "Reflection on Teacher Concern" survey, at the end of each of the two phases during the semester, the participants were requested to write a reflection essay in which they have to list and clearly elaborate all possible concerns about their teaching practice from both anticipated and actual perspectives. Poulou (2007) employed reflective journal that requires the preservice to articulate their teachers' concern over time to study their changes and the method was regarded as valid both pedagogically to promote teachers' reflection and methodologically to collect data. In addition, a valid coding scheme was employed using Fuller's (1974) classification on teacher concern. Table 1 shows the coding scheme and example (with each identified concern as unit of analysis) excerpted from students' reflective writing. As for reliability, two researchers independently coded students' reflective writing into categorized concern types. As a result, the inter-coder reliability was computed to be 0.81.

5. Design cycle 2

5.1. Participants

Participants in the second design cycle were 9 pre-service teachers who took the same "Mathematics Teaching Practice" course. The duration of this study was also an 18-week semester, with same course design of two divided phases (with each lasting for 9 weeks). To address the issue identified form Design cycle 1 (see details in the results), however, the knowledge building principle of "symmetric knowledge advancement" (SKA) (Scardamalia, 2002) was additionally highlighted this time to improve the explanatory quality of feedback/idea. The SKA principle highlights that to give knowledge (via feedback ideas) is to receive knowledge (by becoming able to make sense of existing knowledge and sharing it with other classmates, while at the same time gaining deeper understanding of problems under discussion and accordingly to suggest more explanation-oriented ideas/solutions to the problems). It is posited that by highlighting this principle, students would be able to provide more explanation-oriented feedback/ideas that is conducive to fostering deeper collective reflection and more creative teaching practices.

Table 1
The coding scheme for analyzing teaching concerns.

Code	Definition	Example
Concern about self	Describe concern or information about something not concerned with teaching.	I think it is ok. At least I could pass the course in National X University, so it should be good ~ Ha. (S1)
Concern about self as teacher	Statements about one's own efficacy and adequacy as a teacher, including statements about discipline, instruction, and subject matter adequacy.	I doubt that I can be a qualified teacher. (S5) Although the classroom's atmosphere was very lively, maintaining order in the classroom is also important. (S12) Maybe sometimes I'm too strict and cause learners to feel stressed. (S16)
Concern about learners	Statements about learners' needs, about whether learners are learning what they need, and about methods and means, within the classroom, to that end.	A critical point is that lots of teachers use their own way to interpret mathematics concepts, without taking students' prior knowledge and learning experiences into consideration. (S8) Teachers should not be complacent about their own teaching competence; instead, they need to pursue further professional development, and continually improve their teaching practices, toward the goal of helping every student to learn better.(S8)

Table 2
Coding scheme for mathematics teaching-related knowledge.

Types of teaching knowledge	Description	Example
Content knowledge, CK	Understanding of the subject matter taught	My own understanding of basic mathematical concepts is improved. (S1)
Pedagogical knowledge, PK	Use of teaching approaches and strategies to promote learning, manage the class, and create a proper learning atmosphere.	Balance between lecture and interaction with students is important. (S4)
Technology knowledge, TK	Knowledge to utilize various instructional media, including books, blackboards, PowerPoint, video clips, Internet information, etc.	Using projector and other teaching equipment is essential for me. (S9)
Pedagogical content knowledge, PCK	Understand how to utilize various pedagogical approaches for different teaching content, and select appropriate ones for different classes/teaching purposes.	You can change your teaching design by having some hands-on activities and by re-sequencing your teaching materials from easier to more difficult tasks. (S3)
Technological content knowledge, TCK	Knowledge about effective representation of subject content through media	The representation of materials through equipment is not helpful for learning. (S4)
Technological pedagogical knowledge, TPK	Understand how to use instructional media with various instructional approaches; select proper media for various instructional strategies.	The combined use of projector and blackboard is not helpful or productive as they interfere with each other. (S6)
Technological pedagogical content knowledge, TPCK	Understand how to properly use and combine instructional techniques and media for content instruction.	During the process of lecturing, marking the key points through media is necessary so that the students can understand your points [content] more clearly. (S3)

5.2. Data sources and analysis

Data collection was also the same as in the first design cycle, except for the content of the survey. While it is still used as a reflection tool, for the final reflection, the content of the survey was about teacher knowledge in the 2nd design cycle given the satisfactory reflection results from the 1st design cycle. The analysis procedure for the first and second sets of data also remains the same.

5.3. Instrument

Like in Cycle 1, students were asked to complete a reflective survey at the end of each of the two phases during the semester to report their gained teacher knowledge for their teaching practice. The analysis focused on examining whether there is any change in participants' reflection on the various types of their teacher knowledge over time. To ensure the validity of the instrument in assessing students' teaching knowledge, a coding scheme was employed using Koehler, Mishra and Yahya's (2007) seven types of TPACK knowledge. Table 2 shows the coding scheme and example (with each identified type of TPACK knowledge as unit of analysis) excerpted from students' reflective survey. As for reliability, two researchers independently coded students' reflective writing into categorized TPACK types. As a result, the inter-coder reliability was computed to be 0.84.

6. Results

6.1. Design cycle 1

The main research question in Design Cycle 1 focused on whether the knowledge-building principles, particularly the highlighted “Community Knowledge, Collective Responsibility” principle would help guide the pre-service teachers (1) to work more cohesively as a teacher/design community; (2) to help each other reflect and improve teaching practices through more explanation-oriented feedback/ideas; and (3) to improve their reflective capacity, particularly, by focusing their reflection more on student-centered teacher concern.

6.2. Knowledge Forum activities

As mentioned above, the semester was divided into two phases to allow every pre-service teacher to perform two teaching practices through lesson design and re-design. In the meantime, based on the abovementioned knowledge building principle, the participants were encouraged, and constantly reminded, to work as a reciprocal professional community and to shoulder the collective responsibility of helping one another design and teach better. To this end, they need to provide peer feedback for lesson design ideas in KF each time they observe and evaluate a classmate's teaching practice. Fig. 3 shows an example of a Knowledge Forum view in which students are working with and building on their ideas/conversations with two notes showing procedure and explanation oriented feedback. Each small square in Fig. 3 represents a note; each link between two notes means that a note is building on another note. Table 3 further summarizes the results of online interactions regarding the three main Knowledge Forum (KF) activities. In brief, the number of notes generated indicates the degree of students' overall community contribution, the number of notes read indicates the level of students' awareness of other community members' ideas and activities, and the number of notes built-on in

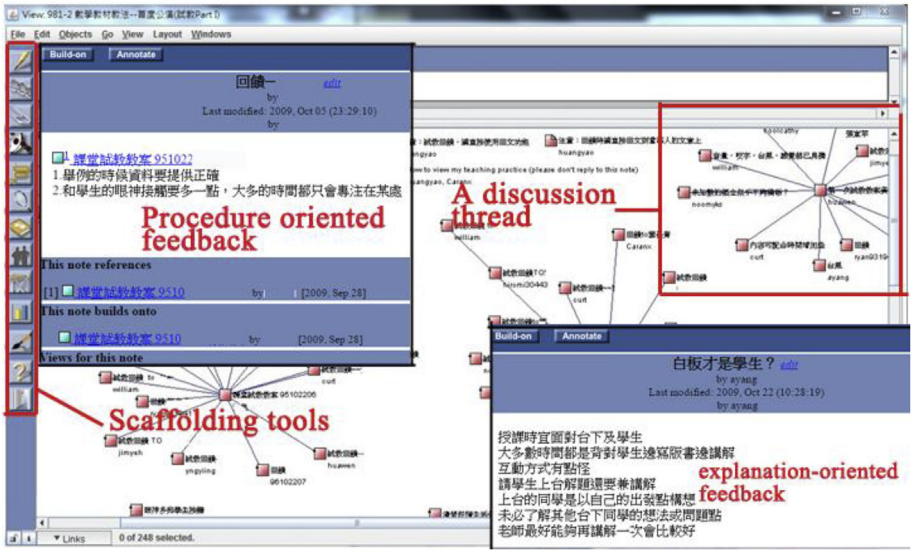

Fig. 3. An example of a Knowledge Forum view in which students are working with and building on their ideas/conversations with two sample notes showing procedure and explanation oriented feedback.

Table 3
Indicators of Knowledge Forum activities (n = 16).

KF activities	Phase 1		Phase 2		*t-value*
	M	SD	M	SD	
Quantity of online interactive activities					
# of notes generated	14.5	5.48	20.06	6.02	2.732**
# of notes read	123.8	69.37	201.47	124.3	2.1826*
# of notes built-on	10.75	5.21	16.38	5.15	3.0741***
Quality of online feedback activities					
Procedure-oriented ideas	6.57 (76.66%)	2.78	5.09 (62.92%)	3.9	1.2361
Explanation-oriented ideas	2 (23.34%)	0.09	3 (37.08%)	2.17	1.8417
# of feedback words written	1327.81	731.06	1582.56	996.96	−1.554

*$p < .05$, **$p < .01$, ***$p < .001$.

particular indicates the extent to which students were able to contribute thoughts, comments, and ideas for the benefit of other community members who have taken turns to practice their teaching. The analysis particularly showed the differences between the two phases in terms of all three KF activities. Overall, paired-sample t-tests indicated that there were statistically significant differences between the two phases in terms of all three main online KB activities. The findings suggest that the time and effort spent on KF was well distributed between the two phases, with progressively more frequent activities occurring in the second phase. The findings suggest that the participants were able to follow the pedagogical guidance based on the target knowledge building principle to work as an interactive and collaborative community (see Fig. 3).

6.3. Quality of feedback

Further analysis was performed in order to answer the question regarding the quality of feedback ideas provided by peers in KF. As each student was required to perform two rounds of teaching practice, a pre-service teacher during his or her round of practice would receive 15 classmates' feedback ideas in each of the two KB phases. For analysis, the total numbers for the two types of feedback ideas were calculated and compared between the two teaching practice sessions. As the bottom part of Table 3 shows, there is a decrease, in percentage, of procedure-oriented ideas, from 76.66% in the first phase to 62.92% in the second phase; and there is an increase of explanation-oriented ideas in terms of percentage from 23.34% in the first phase to 37.08% in the second phase. However, the difference is not statistically significant. Additionally, it was found that there is no significant increase in terms of the average number of words produced per student from the first to the second phase. Overall, there are relatively fewer explanation-oriented ideas. This indicates that the pre-service teachers are predisposed to view teaching as procedural skills and they are not accustomed to seeking explanation, or relating skills to explanations. The reasons why some teaching skills are important and effective are based on some complex interactions between the learners, the learning environment, and the subject matter. Without attending to ideas that explain how things work, i.e. seeking idea-centered explanations, the teacher is less likely to pursue further innovative teaching. The findings indicate that students were learning to become better feedback providers, but there is still room for them to better articulate more explanation-oriented ideas. This finding confirms previous studies in that procedure-oriented feedback

Table 4
Comparison between pre-service teachers' anticipated and actual teaching concerns.

	Actual		Anticipated		t-value
	M	SD	M	SD	
Concerns about self	1.18	1.23	0.39	0.69	2.22 *
Concerns about self as teacher	5.5	2.98	4.36	2.1	1.25
Concerns about learners	1.28	0.94	6.61	2.52	7.91***

*$p < .05$, ***$p < .001$.

is more commonly observed among novice teachers who tend to see teaching practice as a way to demonstrate exemplary teaching skills (Hong et al., 2011). As such, they tend to give feedback concerning the right procedures from the observed teaching practices (see below Design Cycle 2 for solutions to address this issue).

6.4. Outcome assessment

In the present design cycle, participants were asked to reflect on their teacher concern from two perspectives: anticipated concern and actual concern. To begin with, a comparison of teacher concern between participants' two perspectives was performed (regardless of the two phases). As Table 4 shows, it was found that the participants' ratings for both anticipated and actual concern about self as teacher was very high, and there is no significant difference between them ($t = 1.25$, $p > .05$). This may be due to a ceiling effect, as well as their inexperience in actual teaching practice. Further, it was found that participants' rating for actual teacher concern about self was significantly higher than their rating for anticipated teacher concern about self ($t = 2.22$, $p < .05$). In contrast, participants' rating for actual teacher concern about learners was significantly lower than their rating for anticipated teacher concern about learners ($t = 7.91$, $p < .05$). This interesting finding shows that when it comes to actual teaching practice, the participating pre-service teachers are more likely to focus on themselves than on how to facilitate learners. There clearly exists a mental gap between what the participants expect and what they actually do in real teaching. There is still room for pre-service teachers to work towards closing this theory-practice gap.

Specifically, in terms of concern from an anticipated teaching perspective, as shown in Table 5, it was found that pre-service teachers' ratings in "concern about self" ($t = 1.15$, $p > .05$) and "concern about self as teacher" ($t = 0.17$, $p > .05$) were not significantly different between the first and second phases. However, their ratings in "concern about learners" ($t = -5.24$, $p < .05$) was significantly increased from the pre-survey to the post-survey. In contrast, in terms of teacher concern from an actual teaching perspective, students were asked to reflect based on the actual outcomes from their two teaching practices. As Table 5 shows, pre-service teachers' ratings of "concern about self" was not statistically significant ($t = -1.12$, $p > .05$). However, the ratings of their "concern about self as teacher" ($t = -2.64$, $p < .05$) and their "concern about learners" ($t = -6.54$, $p < .05$) were statistically significant for the surveys. The findings indicate that the principle-based activities seemed helpful for engendering pre-service teachers' reflective capacity, focusing not merely on concern about self or self as a teacher, but on concern about learners. Namely, pre-service teachers' concern is extended to be more student-oriented. For example, one participant stated, "A critical point is that lots of teachers use their own way to interpret mathematics concepts, without taking students' prior knowledge and learning experiences into consideration." (S8).

As discussed in the literature review, from the perspective of design thinking (Tsai & Chai, 2012), teaching concerns represent a starting point for teachers to empathize with learners via keen observation and reflection, and then teaching knowledge usually follows to further address problems derived from their concerns. So it is equally important to facilitate pre-service teachers' reflection on their teaching knowledge. As the participants were able to reflect on their teaching concerns from a more student-centered teaching stance in Cycle 1, this gives us confidence to further improve our design with a more advanced focus on teaching knowledge in Cycle 2 (see below for detail). One thing to note is that to ensure there will be no practice effect to interfere with the 2nd design, we

Table 5
Comparison between the 2 phases in terms of specific anticipated or actual teaching concerns.

	Phase 1		Phase 2		*t-value*
	M	*SD*	*M*	*SD*	
Teaching concerns from an anticipated perspective					
Concerns about self	0.5	0.86	0.29	0.47	1.15
Concerns about self as teacher	4.43	1.5	4.29	2.56	0.17
Concerns about learners	5.21	2.42	7.71	2.61	−5.24***
Teaching concerns from an actual perspective					
Concerns about self	1.13	1.2	1.23	1.26	−1.12
Concerns about self as teacher	4.31	1.74	6.69	3.84	−2.64*
Concerns about learners	0.38	0.62	2.19	1.17	−6.54***

*$p < .05$, ***$p < .001$.

Table 6
Indicators of knowledge forum activities (n = 9).

Activities	Phase 1		Phase 2		*t-value*
	M	SD	M	SD	
Online interactive activities					
# of notes generated	8.2	0.92	15.2	0.92	16.14***
# of notes read	86.1	26.6	126	57.3	1.88
# of notes built-on	7.3	0.67	13.8	0.63	21.20***
Online feedback activities					
Procedure-oriented ideas	2.49 (77.57%)	1.02	1.7 (50.30%)	0.8	1.18
Explanation-oriented ideas	0.72 (22.43%)	0.58	1.68 (49.70%)	0.81	2.89**
# of feedback words written	2060.00	596.29	2007.50	739.49	.323

*$p < .05$, **$p < .01$, ***$p < .001$.

decided not to continue study with the same participants after they finished this course, so the participants are different in the 2nd design cycle.

6.5. Design cycle 2

As elaborated above, the two design cycles were both based on the same KB environment in order to foster designerly-oriented teaching practice that is premised on creative lesson design, and both aimed to enhance participants' (1) online interaction and collaboration as a community, (2) more explanatory coherent, idea-centered feedback, and (3) reflective activities. To achieve the above aims, in particular, to improve the explanatory quality of participants' feedback/ideas that was not achieved in Cycle 1, the knowledge building principle of "symmetric knowledge advancement" (i.e., to give knowledge is to gain knowledge) was additionally highlighted in the second cycle. Like the first design cycle, the analyses also focus on Knowledge Forum activities, quality of feedback ideas, and the related outcomes.

6.6. Knowledge Forum activities

Like in Design Cycle 1, the course in the second cycle also required every student to take turns and perform two rounds of micro-teaching in the first and second phases. Table 6 shows the results of students' interactive activities in KF. The upper part of Table 6 summarizes the results regarding students' three main Knowledge Forum activities. The statistics indicate that there were increases for all three main KF activities from the first to the second KB phase. In particular, there were significant increases in terms of the number of notes contributed and the number of notes built-on, but there was no significant increase in terms of the number of notes read. This may have to do with the fact that the "symmetric knowledge advancement" principle was additionally emphasized in this design cycle; as a result, the trade-off is reduced time for online reading. But even so, the overall results regarding online interactions in KF were positive. As with Design Cycle 1, the progressively more contributing and building-on activities in the second KB phase suggest that the pre-service teachers were becoming more collaborative and able to articulate, indicating an improvement in collective reflective community.

6.7. Quality of feedback

In addition, analysis was performed in order to understand if additionally highlighting the "symmetric knowledge advancement" principle before every round of teaching practice as pedagogical guidance would enhance the feedback/idea quality in KF. As the bottom part of Table 6 shows, although the percentage of procedure-oriented feedback ideas over all feedback ideas dropped from 77.57% in the first phase to 50.30% in the second phase, the difference was not significant. However, there was a significant increase of the percentage of explanation-oriented feedback ideas over all feedback ideas from 22.43% in the first phase to 49.70% in the second phase. Additionally, it was found that there is also no significant difference in terms of the average number of words produced per student between the first and the second phase. However, when comparing the second design cycle with the first design cycle, it was found that the average number of feedback words ($M = 3846.67$; $SD = 507.89$) received per student from peers in the whole semester in design cycle 2 is significantly more than the average number of feedback words ($M = 2854.19$; $SD = 646.90$) in design cycle 1 ($t = 15.65$, $p < .001$). The findings indicate that guided by the target guidance principle, students became more likely to improve the explanatory quality of their feedback ideas. The findings also imply that students might become more reflective as giving feedback itself also requires a lot of reflective and critical judgment. The findings overall suggest that the highlighted principle as pedagogical guidance is useful. Overall, students' online Knowledge Forum activities were quite consistent with the principled expectation, that is, to give knowledge is to receive knowledge, by providing rich and quality teaching feedback/ideas to one another for improvement of their teaching practices. Fig. 4 shows an example of highly elaborated feedback that explains reasons why the feedback commenter would design the same lesson differently. For example, the first reason describes why it is important to slow down the instructional pace as this would allow students the necessary time to think and ask relevant questions in class, so that they can actually master the concepts required to move on to the next learning task.

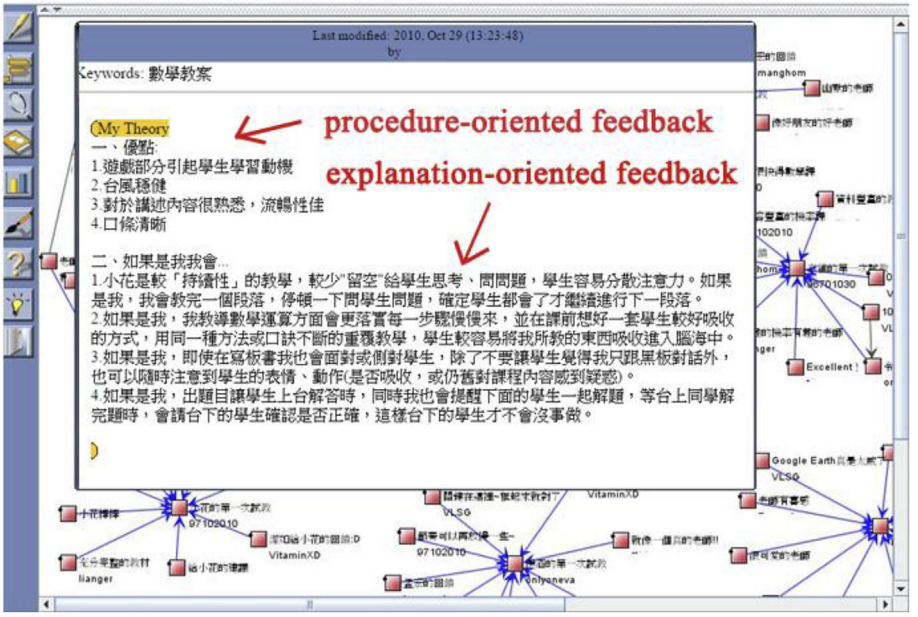

Fig. 4. An exemplary note with highly elaborated feedback (note: while discussion threads look independent of each other in the figure, there is actually a build-on process of them as reflected in students' collective feedback ideas becoming more explanation-oriented over time).

6.8. Outcome assessment

Same as Design Cycle 1, survey was used as a reflection too; but unlike Design Cycle 1 in Cycle 2, the reflective challenge was set to enhance pre-service teachers' reflection on teaching knowledge. For analysis, as Table 7 shows, it was first found that there was a significant difference between the two types of basic and integrated teaching knowledge in the first phase in which more frequent reflection occurred on basic teaching knowledge. This was quite expected as the participants were just beginning to learn to teach. However, in the second phase, it was found this knowledge gap was mitigated. The findings suggest that principle-based guidance for pre-service teachers' teaching practice was able to make them progressively become more reflective on integrated teaching knowledge. To further analyze this change in detail, all seven types of teaching knowledge were examined (see Table 8). As a result, the findings indicate that there were increases in all seven types of teaching knowledge from Phase 1 to Phase 2. However, not all of them were statistically significant. There were a few important observations. The first is that their reflection is highly focused on pedagogy related knowledge (i.e., PK and PCK), as compared with other types of knowledge. This is quite expected as learning “how” to teach is perhaps the most important task for beginning teachers; and the reason why there are no significant differences in these two types of knowledge is very likely due to a ceiling effect. As for the other types of teaching knowledge, it was found that only the increases of CK, TK, and TCK were statistically significant. This specific finding implies that KF activities were helpful to enhance these pre-service teachers' reflective capacity, but their reflection tended to focus on (1) what mathematical content knowledge to be taught, (2) which instructional technology to be used, or (3) what specific type of technology can be used to better enhance students' understanding of certain math content. The reasons may have to do with the fact that most students’ major in education in general rather than in mathematics specifically. Also, it may be because technology-enhanced instruction is widely acknowledged as an important teaching skill. So the participants tended to reflect more on these types of knowledge. Additionally, it may be worth noting that a possible reason for why the increased numbers of reflection on other types of teaching knowledge were not significant might be attributable to the limited time (only one semester) in this study. However, the increase in these three types of teaching knowledge still showed that principle-based guidance via idea-centered activities in this study was still effective. Clearly, additional cycles of design research are necessary to help address these questions and issues.

Table 7
Differences between basic and integrated TPACK in Phases 1 and 2.

	Basic		Integrated		*t-value*
	M	SD	M	SD	
Phase 1	1.78	0.83	0.83	0.57	2.83*
Phase 2	2.78	2.12	1.25	1.6	1.73

*$p < .05$

Table 8
Differences between Phases 1 and 2 in terms of all seven types of TPACK.

Type of teaching knowledge	Phase 1		Phase 2		*t-value*
	M	SD	M	SD	
CK	0.67	0.59	1.89	0.93	3.32***
PK	4.67	1.32	5.56	3.36	0.74
TK	0.00	0.00	0.89	1.17	2.284*
PCK	3.11	1.05	3.78	2.99	0.634
TCK	0.00	0.00	0.56	0.73	2.304*
TPK	0.00	0.00	0.33	0.50	1.98
TPCK	0.22	0.44	0.33	0.71	0.40

*$p < .05$, ***$p < .001$.

7. Discussion and conclusion

The present research investigates the effects of principle-based knowledge building activities on pre-service teachers' reflective capacity. To this end, two iterative design cycles were implemented, with the principles of "community knowledge, collective responsibility" and "symmetric knowledge advancement" being employed respectively in the first and second cycle. The main findings in this research are summarized and discussed below from two perspectives: knowledge building process and outcome.

In terms of the knowledge-building process, in the first design cycle, it was found that students benefitted from the guidance of the "community knowledge, collective responsibility" principle and were able to work as an interactive and collaborative community. It was also found that students were able to provide more explanation-oriented, and less procedure-oriented, feedback comments, but the statistics showed no significant differences (so, the second "Symmetric Knowledge Advancement" principle was additionally highlighted in the second design cycle). Second, in the next design cycle, it was found that the repeated use of the "community knowledge, collective responsibility" principle to guide pre-service teachers' online interaction as a community was again able to produce similar positive results with students' online knowledge work being highly interactive and collaborative. Further, additional emphasis on the "Symmetric Knowledge Advancement" principle was found to be useful in that the amount of explanation-oriented feedback was significantly increased in the second phase. The finding indicates that pre-service teachers were able to realize the value of "giving knowledge is gaining knowledge," and to provide one another with more explanation-based quality feedback for improving each other's teaching practices. Our findings confirm our argument for the importance of idea-centered reflection to go beyond reflection on personal thoughts that exist only in human's mind or what Popper (1987) called the 2nd epistemic world, to collective reflection on ideas that Popper referred to as the World-3 epistemic objects. The findings basically suggest that it is possible to facilitate social reflection by using idea-centered, collaborative peer feedback to foster the reflective development of one's teaching practices (Jones & Gallen, 2016).

In terms of knowledge building outcomes, in the first design cycle, it was found that pre-service teachers were able to significantly enhance their reflective capacity by increasing their "teaching concerns about learners" from the first to the second phase. But, additional comparison between their anticipated and actual teaching concerns also suggest (1) that participants' ratings for both actual and anticipated teaching concerns about self as teacher were very high, and no significant difference was found between them; (2) that participants' rating for actual teaching concerns about self was significantly higher than their rating for anticipated teaching concerns about self; and (3) that participants' rating for actual teaching concerns about learners was significantly lower than their rating for anticipated teaching concerns about learners. Apparently, there exists a misalignment between anticipated and actual teaching concerns that need to be further investigated. Additionally, being able to successfully increase participants' concern about learners through more explanation-oriented feedback ideas, this study shows the potential to change how preservice teachers design instruction. Angeli and Valanides (2009) has highlighted the need to empathize with students' learning difficulties as a beginning point for instructional design. In this study, the broadening of teachers' concerns has helped the preservice teachers to notice more learners' needs, which is essential for good instructional design (Kali et al., 2011; McKenney et al., 2015). Further, using survey as a means for teaching reflection, in the second design cycle, further instructional attention was directed to pre-service teachers' reflection on their teaching knowledge. As a result, it was found that the participants were able to progressively reflect more on integrated than basic teaching knowledge. In addition, it was found that among all seven types of teaching knowledge, the participants were able to significantly enhance the extent of their reflection on CK, TK, and TCK. Current research in TPACK has emphasized the importance of relating different domain of knowledge in order to transform instruction through design thinking (Angeli & Valanides, 2009; Koh et al., 2015; Mishra & Koehler, 2006). The findings of this study indicates that the participants were able to achieve in-depth reflection on the strengths and weaknesses of their lesson design ideas and enactment, in terms of content knowledge and technological knowledge. Moreover, the significant increases in participants' reflection on TCK also indicated that the participants were able to think deeper about the important integrated use of technology for teaching math content. At the same time, this also means that for novice/pre-service teachers, emphasizing reflection on teaching knowledge is essential while they practice to gain more practical teaching experience, and it is also important for them to further reflect on how to integrate different core knowledge (i.e., content knowledge, pedagogical knowledge, and technological knowledge) into more sophisticated teaching knowledge (e.g., technological pedagogical content knowledge).

In conclusion, the importance of this study is threefold. First, internationally there is a clear shift of research focus from individual to communal perspective, asserting that teachers need to work collaboratively to learn to share, discuss, and solve what they do not know by co-constructing new teaching ideas and practices (Darling-Hammond & Bransford, 2005; Tseng & Kuo, 2014). In response to this change of research perspective, our study identified a possible pedagogical approach to fostering such community-based teaching-learning that is also in line with the educational reform within the Taiwan context. Second, there is also an increasing trend of research on the concept of teachers as designers (Chai et al., 2018; Kali, McKenney, & Sagy, 2015; Makkia et al., 2018). The present study also adds to this line of research to suggest the importance of having teachers engage in collective reflective and feedback activities to reciprocally improve one another's lesson design ideas as a way to developing a teacher-as-designer mindset. Third, as design essentially requires teachers to empathizing with student needs (i.e., student-centered concerns) and integrating various types of knowledge resources (i.e., TPACK), this study engage teachers' in empathetic thinking through surfacing their concerns and responding to the concerns using a wide variety of knowledge resources. The findings in this study also suggest that the participating teachers are gradually improving their design capacity or design fluency that is required for sustained design and teaching improvement (Hong et al., 2009).

The study has two important implications. First, previous studies suggest that novice teachers tend to reflect more on teacher-centered teaching concerns and core teaching knowledge (Boz, 2008; Kyriacou & Stephens, 1999). Overall, the results based on the pre-surveys in both design cycles 1 and 2 in the present study were consistent with the findings of past studies. However, in the post-survey reflection, it was found that students became more able to reflect on student-centered teaching concerns and integrated teaching knowledge. In Taiwan, the educational reforms have started to request pre-service preparation to pay more attention to developing future teachers using more student-oriented instructional approaches and models. As such, the findings in the present study have important implications for teacher preparation institutions in terms of student-centered pedagogical reform. Our research indicates that by engaging pre-service teachers in more adaptive, idea-centered knowledge work, it is likely to help re-direct their reflective teaching on more student-centered factors and more integrated teaching knowledge.

The second important implication is particularly concerned with the use of knowledge building principles. The two highlighted principles concerned in the two cycles seemed to be effective in guiding the prospective teachers to play the role of designers and to work reflectively with their lesson design ideas for continuous improvement. In the present study, knowledge building activities emphasizes communication among members to improve each other's lesson design ideas. The implementation of knowledge building principles of “community knowledge, collective responsibility” and “symmetric knowledge advancement,” required the participants to collaboratively work as a design community in KF. In the first teaching cycle, the focus of principle is on “community knowledge.” As such, participants tended to focus on online interactions, not necessarily the quality of lesson design ideas. So in the second design cycle, the additional principle, “symmetric knowledge advancement” was employed to highlight “to give knowledge is to get knowledge.” It turns out that this principle played an effective complementary role in transforming a teacher community into a design community which has even more direct impact on teachers' lesson design activities.

In conclusion, it is confirmed that principle-based knowledge-building pedagogy is useful for engaging the participating pre-service teachers in a more reflective way of knowing and teaching. Such principle-based guidance is in sharp contrast with proceduralized, task-oriented, or ritualistic pedagogical guidance which highlights the use of procedures, tasks, rituals, routines, manuals, scripts, or clearly-defined activities to help pre-service teachers to master core teaching knowledge and skills (cf. Adams & Engelmann, 1996; Harford & MacRuairc, 2008; Radloff & Guzey, 2017; Sawyer, 2004, 2006). On the contrary, principle-based guiding heuristics, allows the necessary autonomy for teachers to tinker with their teaching ideas for lesson design and knowledge creation. Under this approach, more adaptive and reflective design activity becomes a natural part of their micro-teaching process; and thus, it is more likely to help the development of their creative teaching mentality. The findings from these two design cycles represent an important start toward a deeper understanding of knowledge building principles in relation to the development of teacher-as-designer community.

There are admittedly some limitations. As there were no control groups, we have no evidence to suggest a strong causal relationship between the implementation of specific principle-based KB activities and the improvement of their reflective and design capacity. But, even so, the current evidence enabled by the present design-based research can still suggest that the overall knowledge-building activities, among other possible factors, are conducive to the positive development of participants' reflective thinking capacity. Admittedly, there are still many open questions that remain to be answered. Further analysis will be conducted to triangulate the findings derived from the two cycled studies and to better answer the research questions.

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Appendix 1. The 12 Knowledge Building Principles (Scardamalia, 2002; Scardamalia & Bereiter, 2010)

- Real ideas, authentic problems: Ideas are viewed as conceptual artifacts that can be worked and molded like physical objects and ideas are produced to solve knowledge problems that emerged from efforts to understand the world.
- Idea diversity: Comparison, selection and synthetic transformation of diverse ideas are a necessary part of sustained knowledge building.
- Improvable ideas: All ideas are viewed as improvable for community knowledge advancement.

- Rise above: Working towards higher-level understanding of problems and explanatorily more powerful ideas are critical for advancing community knowledge.
- Community knowledge, collective responsibility: Shared collective cognitive responsibility in the community is essential for achieving their overall community knowledge goal.
- Pervasive knowledge building: Knowledge construction activities permeate learners' mental life–both offline and online, and also in and out of school.
- Democratizing knowledge: All members are regarded as legitimate knowledge contributors in the community.
- Symmetric knowledge advancement: Community highly values distributed expertise and is committed to growing each other's knowledge.
- Epistemic agency: Members in the community are expected to deal with all aspects of knowledge problems.
- Knowledge-building discourse: The goal of community's dialogical interactions are focused on fostering deeper intellectual advancements
- Constructive uses of authoritative sources: Existing authoritative knowledge sources are treated as ideas that need to be studied critically to advance inquiry at hand.
- Concurrent, embedded, transformative assessment: Participants are encouraged to engage in self-initiated and self-directed assessment rather than relying on external assessment.

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