Chapter 11
Developing Student-Centered Teaching Beliefs Through Knowledge Building Among Prospective Teachers

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Introduction

The emphasis on cultivating more effective teachers who, in turn, will help to prepare more creative students to tackle future societal problems has become the focus of educational reform in many advanced countries. Teachers play an important role in education as the way they teach can directly and indirectly influence what and how students learn (Cooney 1994; Ernest 1989). The success of educational reform, therefore, depends greatly on whether teachers can perform their jobs productively and effectively.

All other things being equal, an important factor affecting teacher performance has to do with teaching beliefs (Thompson 1992). Given its importance as a major influence on the quality of teaching (Clark and Peterson 1986), it is beneficial that teachers are aware of the existence of different teaching views and beliefs. This is especially important for teacher-education students in Taiwan, who are used to receive a more conventional teacher-centered instruction (Hong et al. 2011). As such, they are generally not aware of alternative teaching views such as the constructivist-oriented teaching stance (Hong and Lin 2010). To help broaden their teaching views, it will be beneficial if they are guided to experience a more student-centered/constructivist-oriented learning process, which is in sync with the current education reform movement in Taiwan. Doing so may also help teacher-education students to be more willing to experiment with, and reflect on, more diverse instructional approaches. To this end, this study employed a constructivist-oriented instructional approach called knowledge building to help provide teacher-education students with opportunities to experience more constructivist-oriented learning and to reflect on their teaching beliefs. As an innovative pedagogy, previous studies suggest that knowledge building is likely to foster more

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constructivist-oriented learning environments (e.g., Chai and Tan 2009; Hong and Lin 2010; Hong et al. 2011). It is posited that, with proper course design, knowledge building can also help guide teacher-education students to practice more diverse and flexible teaching and thus develop more student-centered teaching beliefs and practice. Accordingly, the main research question is: How does knowledge building affect teacher-education students' teaching beliefs and practices? Specifically, we looked into participating teacher-education students' pre-post belief change, online learning activities, and their videotaped practice change in class.

Teaching Beliefs

What is belief? To clarify the concept of belief, it may be helpful to understand its relationship with knowledge. According to Dretske (1981), knowledge is confirmed or sustained belief. Belief represents a person's subjective value judgment, whereas knowledge represents an objective, neutral accumulation of facts about the world surrounding us. In terms of teaching beliefs, it is possible that teachers might have similar subject (e.g., mathematics) knowledge but employ very different teaching approaches (e.g., teacher-directed lecture vs. student-initiated inquiry) due to different teaching beliefs. Beliefs can explicitly or implicitly guide a teacher to decide what and how to teach and thus can affect the results of what and how knowledge should be delivered to or acquired by students (Clark and Peterson 1986; Peterson et al. 1989; Schwartz and Riedesel 1994).

There are, in general, two types of teaching beliefs: teacher-centered and student-centered (Ernest 1991; Handal 2003). When a teacher's teaching beliefs are more teacher centered/content oriented, he/she is more likely to assume teachers to be authorities for imparting knowledge to students. Whereas when a teacher's teaching beliefs are more student centered/constructivist oriented, he/she is more likely to highlight teaching as a means to facilitate students in exploring and deepening knowledge (Kember, 1997) or even as a means to creating or building knowledge (Bereiter 1994; Hong and Sullivan 2009; Scardamalia 2002).

While teaching beliefs are suggested as a key factor that influences teaching practice (Clark and Peterson 1986), previous research findings concerning the causal relationships between teaching beliefs and practice are not at all consistent (Thompson 1992). Instead of a linear causal relationship between teaching beliefs and teaching practice, studies suggest that there exist other possible reasons to explain the relationships between teaching beliefs and practice. For example, Thompson discovered inconsistency between teaching beliefs and teaching behaviors; he found that there were multiple factors simultaneously affecting teaching practice, and belief is just one of them. Handal (2003) expressed a similar view, arguing that beliefs and teaching practice could mutually influence each other. Other studies suggested that even teachers who hold more constructivist-oriented or student-centered teaching beliefs may not necessarily be able to put such beliefs into practice due to certain contextual factors or limitations (e.g., school culture).

Ernest (1989) also stated that the process of transforming beliefs into practice could be affected by many factors. These can include social and cultural factors (e.g., expectations from parents, principal's leadership, and social value) (Thompson 1992). In addition, a teacher's reflective ability can also affect the way they practice teaching. It was argued that teachers who were more reflective are more likely to develop more sophisticated teaching beliefs (Schön 1983). More importantly, teaching beliefs are usually developed over a long period and are largely influenced by a teacher's past learning experiences (Calderhead and Robson 1991; Nespor 1987) such as their learning experiences during the period of teacher education. Teaching beliefs usually also involve personal values and are often supported by certain implicit assumptions that teachers themselves may not necessarily be aware of (Handal 2003). Therefore, while not at all impossible, it is usually difficult to change teaching beliefs that requires a lot of effort in instructional design (Brousseau and Freeman 1988; Feiman-Nemser and Melnick 1992; Raths 2001; Simon and Schifter 1991).

To design an effective teacher-education curriculum or instruction, in order to help prospective teachers change their teaching beliefs and practices, many factors need to be taken into consideration. For example, it might be worthwhile fostering reflective thinking ability among prospective teachers through an instructional or curricular design (Brousseau and Freeman 1988; Feiman-Nemser and Melnick 1992; Raths 2001; Simon and Schifter 1991). It would also be helpful if the designed activities were able to facilitate prospective teachers to reflect on both their teaching beliefs (Stuart and Thurlow 2000) and teaching practice (Van Zoest et al. 1994) while progressively experimenting with different instructional approaches (Anderson and Piazza 1996). To make this reflective process even more effective, Wilkins and Brand (2004) also suggest that collaborative learning be employed as a means of strengthening reflection, especially social reflection. As Sigel (1985) stated, beliefs are a product of both individual reflection and social interaction, that is, they are an individual's psychological construction of social lives and experiences. As teaching beliefs are in great part shaped by one's past learning experiences (Calderhead and Robson 1991; Nespor 1987), in order to help teacher education develop more informed teaching beliefs, it is important to design a learning environment that avoids replicating a student's previous learning experience. As such, knowledge building may be a worthwhile option for change as it represents a new learning approach that values both reflective and collaborative learning experiences.

Knowledge-Building Pedagogy and Technology

As a deep constructivist theory, knowledge building is defined as a social process focused on sustained production and improvement of ideas of value to a community (Scardamalia and Bereiter 2006). Knowledge-building theory has been represented in the *Cambridge Handbook of the Learning Sciences* as one of a few important breakthroughs in the learning sciences field, along with others such as constructionism, cognitive apprenticeship, and situated learning (Sawyer 2006). Arguably, knowledge building can provide teacher-education students with a more constructivist-oriented and collaborative learning experience and can transform the learning experience from one that highlights passive and individualized knowledge growth to one that highlights more active, reflective, and collaborative knowledge exploration. Specifically, knowledge building encourages group knowledge innovation rather than individual knowledge acquisition. As a pedagogy, knowledge building aims to (1) consider knowledge advancement as a group achievement instead of individual achievement, (2) consider knowledge advancement as a sustained improvement of ideas instead of a path leading to absolute truth, (3) transform knowledge-telling activities into knowledge-exploring activities, (4) make good use of community discourse to solve problems, (5) challenge authoritative sources for constructing new knowledge, and (6) collectively validate the newly constructed knowledge (Scardamalia and Bereiter 2006), for example, through feedback and peer review. These pedagogical suggestions are critical in designing a knowledge-building environment that is different from the conventional classroom environments in most teacher-education programs in Taiwan. It is posited that engaging teacher-education students in knowledge building can guide them to practice their teaching in a more adaptive and innovative manner, rather than in a ritualistic manner based on certain teaching scripts. As maintained by Sawyer (2006), conventional approaches to teaching preparation and development tend to favor script-based, direct instruction. Some disadvantages of such an instructional approach are that they may neglect a teacher's creative personality and standardize instructional activities by repeatedly applying the same instructional strategies to address recurring teaching problems. In contrast, a knowledge-building pedagogy can flexibly allow students to initiate, explore, and self-regulate their own learning. It is believed that doing so can help progressively transform prospective teachers away from taking the role of teacher as an authority figure, who sees knowledge as absolute truth, to taking the role of a teacher as facilitator, who fosters a knowledge-creating environment. Therefore, as an innovative instructional approach, this study adopted knowledge-building pedagogy for designing class activities (Scardamalia 2004).

To support knowledge-building pedagogy, a software called Knowledge Forum (KF)—an online platform that runs on a live database—was developed (Scardamalia 2003) to transform idea aversion (Papert 1991) into sustained idea improvement (Scardamalia and Bereiter 2006). It was unlike most online knowledge tools in which idea improvements are usually not valued. For example, Wikipedia focuses on compiling existing knowledge rather than encouraging idea production and improvement. In contrast, KF enables ideas to be externalized from one's thinking and to be constantly revisited for further development. KF makes it possible for users to simultaneously contribute their ideas in the form of notes online, read or reply to other notes, search and retrieve ideas embedded in notes, and organize notes into more complex knowledge representation. KF also shows linkages of postings as a way to represent the dialogical and interconnected nature

Fig. 11.1 A Knowledge Forum view

of ideas. As such, it also enables the development of ideas to be traced. Figure 11.1 illustrates an example of a KF view (i.e., an open space designed for collaborative learning and reflection), within which users are guided to work as a community by posting their problem of interest, producing initial ideas for problem-solving, sharing and synthesizing ideas, and deepening their collective understanding of the problems at issue. Specifically for this study, the main problem of interest is concerned with understanding the nature of mathematics teaching (e.g., "What represents a good mathematics learning environment?").

Method

Context and Participants

The present research was conducted in a "mathematics teaching" course in a national university in Taiwan. The course was offered by the university's Center of Teacher Education to college students who plan to become mathematics teachers at the middle school level. The university is ranked as one of the best universities in the nation and the students enrolled in the university are all high academic achievers considered by society as the elite prospective teachers in the nation. Participants in this study include four female and five male teacher-education students and their ages ranged from 19 to 23 years.

Instructional Approach

The participating teacher-education students were guided to engage in a knowledge-building process during their teaching practice in this study (Hong et al. 2009). The main purpose of doing so was threefold: (1) to help them avoid viewing teaching as merely pursuing the best practices of certain model teachers by means of mastering predefined teaching skills, (2) to guide them to continually think about how to go beyond "best practices" and assume the role of knowledge workers in the continual improvement of their own teaching practice, and (3) to help them implement teaching as a creative and adaptive knowledge-creating process (Sawyer 2006; Scardamalia and Bereiter 2006). The course was divided into four related phases:

1. Initial idea generation: Participants were guided to work on their initial ideas in order to implement their first teaching practice. Accordingly, they prepared lesson plans, learning materials, learning sheet, etc.
2. First teaching practice: Based on their initial teaching ideas, the participants performed their first teaching practice in class, with their classmates serving as audience. Each student's teaching practice was entirely videotaped.
3. Idea improvement: The participants worked collectively online in Knowledge Forum to provide feedback and suggestions to the student who already implemented their teaching ideas into practice. They then further reflected on these suggestions for idea improvement, analyzed the recorded video of their own teaching practice, and reflected with peers to improve their initial ideas by producing a new lesson plan.
4. Second teaching practice: Finally, based on the improved ideas, each participant performed their second teaching practice. The whole teaching process was again videotaped.

KF was used to support the above idea generation and improvement activities. To this end, a tutorial lesson about the use of KF was administered before the beginning of the class. Teacher-education students were guided to use basic features of KF, for example, contributing a note in a KF "view" (i.e., an online discussion space), building on a note, and annotate. To initiate a completely new idea, the participants would need to create a new note. To elaborate, enrich, exchange, or improve ideas, the participants would then build on a note or annotate by providing comments or suggestions. In addition, the course also employed other complementary instructional activities, including whole-class and small-group discussion after each participant's teaching practice, in order to engage the participants in sustained reflection on improving teaching practice. Some questions discussed in class were: What have you learned from others' feedback? Did you see anything worth further discussion? If you were to teach this lesson again, what would you do differently to improve it, and why? The instructor served as a facilitator in guiding class students to explore and discuss the questions that emerged in class in order to help them reflect on their own beliefs about mathematics teaching. KF was only used after class, and it played an important function as a place for the class students to document all key teaching ideas reflected and generated from class discussion activities.

Data Source and Analysis

The data source included a belief survey (which was administered at the beginning and the end of the semester), online feedback and discussion (which were recorded in the KF database), and student teaching practice (which was entirely videotaped throughout the whole process). To explore students' knowledge-building outcome, we analyzed data collected from the belief survey. The coding scheme was based on Handal's (2003) conceptualization of two types of mathematics beliefs concerning the nature of mathematics teaching (see Table 11.1). In this survey, we asked the following questions adapted from Tsai (2002): (1) What is the ideal way to teach mathematics? (2) What are some key factors for successful mathematics teaching? (3) What makes an ideal mathematics teacher? (4) What is the ideal way to learn mathematics? (5) What are some key factors for successful mathematics learning? (6) What does an ideal mathematics learning environment mean to you? To analyze the survey data, we employed an open coding procedure (Strauss and Corbin 1990). Seven codes emerged as shown in Table 11.1. Inter-coder reliability was computed to be .91, using the Kappa coefficient. Nonparametric Wilcoxon signed-rank test was employed to examine whether there were any pre-post differences.

To better understand the knowledge-building processes, we analyzed the online learning activities and process of (videotaped) teaching practice in class. In terms of online student learning/discourse recorded in the KF database, we analyzed basic online KF activity (e.g., notes created and notes read) and interaction patterns by employing descriptive analysis and social network analysis. In terms of student teaching practice, the two cycles of videotaped teaching practice for each participant were content analyzed based on a predetermined coding scheme highlighting the following three general types of learning activity: active, passive, and interactive (Collins 1996). Active activities include independent seatwork, hands-on exercises, practicing quizzes, and the like. Passive activities include lectures, demonstrations, asking factual questions, and the like. Interactive activities include group discussion/debate, group work, and/or collaboration. We examined the percentage of time spent in each type of activity during each teaching practice, using the activity as the unit of analysis. In particular, we presented a representative student's teaching to illustrate in detail how students changed their beliefs during the teaching-as-knowledge-building process.

Table 11.1 Teacher-centered vs. student-centered beliefs in mathematics teaching

Code	Example
1. Teacher centered	
1.1. Lecture	Teaching by telling learners how to do calculation while using visual aids. Doing so can give learners a clear impression about what is taught and help them memorize it (S02)
1.2. Demonstration	Teaching by giving examples and demonstrating how to complete a math quiz and then asking learners to do some exercises (S01)
1.3. Teacher-initiated questioning	Teaching by asking learners to answer some questions that were taught at the same time could help learner be more attentive. It can also help find out whether learners are really learning or not (S07)
2. Student centered	
2.1. Guided problem-solving	Guiding learners to thinking and solving problems can help them better understand the purpose of certain mathematics equations (S03)
2.2. Discussion among learners	It represents a good learning environment if learners can discuss things with one another whenever and wherever they can (S05)
2.3. Student-directed questioning	Waiting for learners to pose questions or encouraging learners (especially those who fall behind in class) to ask questions (S05)
2.4. Discourse and discussion between the teacher and learners	I think the key to influencing the quality of teaching is the interaction between teacher and learners. Teaching without the help of such interaction is like rote learning (S08)

Note: S + number (e.g., S03) refers to a specific participant

Results and Discussion

Mathematics Teaching Belief Change as Knowledge-Building Outcome

We first looked into whether engaging participants in knowledge-building activities had an effect on their mathematics teaching beliefs. As shown in Table 11.2, in terms of teacher-centered mathematics teaching beliefs, there was a significant drop in ratings from the pre-survey ($M = 5.33$) to the post-survey ($M = 2.56$). In contrast, in terms of student-centered mathematics teaching beliefs, there was a significant increase in ratings from the pre-survey ($M = 2.44$) to the post-survey ($M = 9.67$). Overall, the findings suggest that at the beginning of the semester, teacher-education students tended to consider that mathematics teaching was chiefly a means to deliver knowledge (e.g., by giving lectures or by demonstrating certain procedural knowledge to learners). Apparently, they assumed that teachers should focus their instructional goals on helping learners acquire appropriate core

Table 11.2 Mathematics teaching belief change after knowledge-building activities

	Pre-survey		Post-survey		
	M	SD	M	SD	z-value
Teacher-centered	5.33	1.94	2.56	1.88	−2.68**
Student-centered	2.44	1.51	9.67	3.87	−2.43*

*$p<.05$; **$p<.01$

mathematics knowledge or skills through routine mathematics practice. After a semester, however, the participants changed their beliefs and they were able to view mathematics teaching from a more student-centered, constructivist-oriented stance; it is likely that the teaching-as-knowledge-building process helped them gradually realize that routine practice may not necessarily help learners to use mathematics in an exploratory and constructive way. So they began to appreciate mathematics teaching as a way to guide learners to seek and explore patterns and orders and as a tool to help learners engage in more meaningful learning and problem-solving.

Knowledge-Building Process

Overall Online Activity

The overall online activity and performance in this class community are shown in Table 11.3. Throughout the semester, participants contributed a total of 171 notes with a mean of 17.8 (SD = 4.29) notes per person. In addition to note creation, other major online knowledge-building measures recorded in this community were number of notes read, percentage of notes read, number of annotations, number of note revisions, number of build-on notes, and percentage of notes linked. Overall, the amount of online activities revealed in the present study was quite similar to previous research using teacher-education students as participants (Hong and Lin 2010; Hong et al. 2011). Nevertheless, these behavioral measures only gave a general picture of how participants worked online in this database. They did not provide much information about how participants actually interacted with one another. To better understand the social dynamics of the community, a social network analysis (SNA) focusing on network density was conducted.

Interaction Patterns

SNA was conducted using two key indicators that can be extracted from the Knowledge Forum database: "note-reading" (which indicates community awareness of contributions made by other peers) and "note building-on" (which indicates contributions by the effort used to build on to others' work and ideas). Table 11.4 shows the detailed results of participant interactions in two knowledge-building stages (the first vs. second teaching practice). This particular analysis employed an

Table 11.3 Descriptive analysis of online activities

Activity	Mean	SD
No. of notes created per person	17.8	4.29
No. of notes read per person	140.2	32.94
Percentage of notes read per person (%)	82	19.26
No. of annotations per person	21.2	12.26
No. of note revisions per person	8.2	3.29
No. of build-on notes created per person	11.3	2.49
Percentage of notes linked per person (%)	64.3	6.17

Table 11.4 Social network analysis (SNA) of interactivity in the community

Network density	Stage 1 (first teaching practice)	Stage 2 (second teaching practice)	Whole semester
Note reading	100 %	100 %	100 %
Note building-on	72.22 %	94.44 %	100 %

indicator, "network density," which is defined as the proportion of connections in a network relative to the total number possible. The higher the number of the density is, the stronger the implied social dynamics of a community. The intention in adopting knowledge building in this course was to transform the traditional knowledge-transmission mode of learning into a knowledge-construction mode of learning that engaged learners in collective problem-solving and knowledge work. It was, therefore, expected that learners would progressively work more collaboratively in KF. As expected, there was an increasing trend of social interaction as reflected by the measures of density recorded online for this community from the first to the second stage of teaching practice. Lipponen et al. (2003) regarded a social network density of .39 for learners building on each other's online messages as adequate. In the present study, the density level was .72 (for stage 1) and .94 (for stage 2), which indicates a fairly strong social dynamics in this community. The SNA findings alone, however, did not tell us much about the quality of interaction in the community. So we conducted content analysis on participants' notes to discover what they actually did to help each other improve their teaching practices.

Table 11.5 shows the total amount of group feedback and personal reflection made after the first, and before the second, teaching practice, in terms of three dimensions: instructional design, learning materials, and presentation skills. There were 106 suggestions/comments in total and 43 occurrences of personal reflections being made. On average, each student received 13.25 suggestions in each practice from other peers and correspondingly made 4.78 personal reflections. This suggests that participants' online interaction was both quite purposeful and practically oriented toward teaching improvement. The next question was how online interaction, group feedback, and personal reflection contributed to the change of student's actual teaching practice.

Table 11.5 Group feedback and personal reflection made after the first teaching practice and before the second teaching practice

Source of ideas	Area of idea improvement	Frequency
Ideas from group feedback	1. Instructional design	44
	2. Learning materials	28
	3. Presentation skills	34
Ideas from personal reflection	1. Instructional design	16
	2. Learning materials	14
	3. Presentation skills	13

Table 11.6 Percentage of time spent in different instructional activities in two teaching practices

Activity	First practice (%)	Second practice (%)	*t*-value
Passive learning	72.1	46.9	5.04**
Active learning	17.9	36.4	−3.79**
Interactive learning	10.0	16.7	−2.15
Total	100.0	100.0	

**$p < .01$

Practice Change

Overall Analysis. Video analysis was conducted to further understand the way the participants changed their teaching practice. Table 11.6 shows the results in terms of percentage of time spent in three different instructional activities from the first to the second teaching practice. It was found that there was a significant decrease in the percentage of time spent in passive learning activities, from the first practice (72.1 %) to the second practice (46.9 %) ($t = 5.04$, df = 8, $p < .01$). In contrast, there was a significant increase in the percentage of time spent in active learning activities, from the first practice (17.9 %) to the second practice (36.4 %) ($t = -3.79$, df = 8, $p < .01$), and a slight, but not statistically significant, increase in the percentage of time spent in interactive learning activities ($t = -2.15$, df = 8, $p = .064$). This implies that the participants were still hesitant to try more interactive and collaborative learning activities in class. This is clearly an area for further instructional improvement and future study. But, even so, overall, the video analysis confirmed that participant teaching practice was shifting from a more teacher-centered approach to a more student-centered approach.

A Case Example. Figure 11.2 further illustrates the case of a selected student, chosen for its typicality, in terms of her change from the first to second teaching practice. Using open coding, the main themes in Table 11.1 were adopted for the analysis of teaching activities, which can be divided into teacher centered (including lecture, demonstration, and teacher-initiated questioning) and student centered (including students' independent problem-solving, discussion among students, student-initiated questioning, and discussion between the teacher and students).

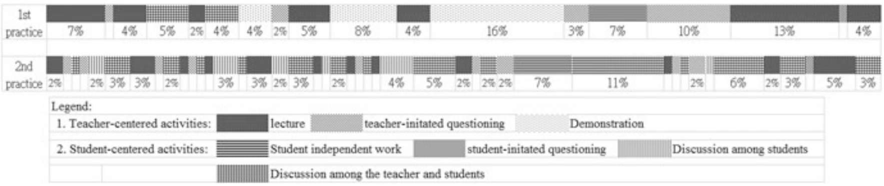

Fig. 11.2 Percentage of time spent in different instructional activities between the two teaching practices (*Note*: The percentage value is not shown in the figure if less than 2 %)

In her first teaching practice, she taught the arithmetic operation of "radical expressions." More than 50 % of her instructional time was spent on teacher-centered activities such as lectures (38.49 %), demonstrations (28.23 %), and teacher-initiated questioning (16.31 %). As the video showed, she hoped that students would learn the content she taught as quickly as possible. There was little time spent on more student-centered activities such as discussion between the teacher and students (8.6 %), independent problem-solving (7.39 %), or student-initiated questioning (0.98 %). The video also showed that the process of interaction between the teacher and students was mainly focused on monitoring students' learning progress and making sure those students completed the assigned exercises. The same topic was taught in the second teaching practice, but it was noteworthy that the teaching approach changed dramatically. She did not directly lecture and teach mathematics concepts and equations; instead, she guided students first to discuss related concepts and equations. Consequently, compared with the first teaching practice, she spent much more time (47.99 %) in discussion between teacher and students and greatly reduced her lecture time (from 38.96 % in the first practice to 22.42 % in the second practice). Overall, the video showed that the main difference in the second teaching practice included activities such as encouraging students to discuss problems together, proposing and testing new solutions/ideas for addressing related mathematics problems, and clarifying and explaining their ideas or the related mathematics concepts discussed.

As illustrated above, this student's initial teaching belief was very teacher-centric. Indeed, the teaching of other students on this course was similar, and this is perhaps because most students' past learning experiences were teacher centered. The illustration of this representative case suggests that student teaching beliefs could become more student centric after engaging in knowledge-building activities. The illustration also suggests the effectiveness of knowledge-building pedagogy in changing student beliefs as it encouraged sustained idea improvement rather than repeated practice on same teaching skills. As such, students were more willing to design more innovative lessons and to open the possibilities for adopting more student-centered activities.

Discussion and Conclusion

In this study, we reported the way an instructional approach designed based on knowledge-building theory and pedagogy and implemented among a group of teacher-education students influenced their views and practice of mathematics teaching. In summary, the pre-post belief analysis indicated that there was a significant decrease in self-reported ratings from the pre- to the post-survey in terms of teacher-centered beliefs. In contrast, there was a significant increase in self-reported ratings from the pre- to the post-survey in terms of student-centered beliefs. Moreover, video analysis showed the participating teacher-education students were able to shift from a teaching mode that highlighted passive learning to a teaching mode that featured more active learning.

The knowledge-building instructional approach highlighted the continual production and improvement of ideas in pursuit of deeper understanding of the nature of mathematics teaching. In summary, the findings indicate that (1) in contrast with the conventionally more didactic instructional approaches commonly seen in Taiwan, knowledge building as an alternative instructional approach was helpful in promoting more interactive and reflective online activities, and (2) after being engaged in knowledge building for a semester, teacher-education students were able to shift away from more teacher-centered teaching beliefs and practice to more student-centered teaching beliefs and practice. Previous studies suggest that preservice teachers (including teacher-education students) are more likely to adopt lectures as a major teaching strategy during their internship and the early years of their teaching career (Fuller 1969; Fuller et al. 1974; Hascher et al. 2004; Rhine and Bryant 2007; Weinstein 1990). They tend to emphasize teaching methods that can quickly impart substantial amount of knowledge to students, and as such, they tend to expect students to submissively receive knowledge passed down via their direct instruction. In the present study, as the survey showed, before engaging in knowledge building, teacher-education students indeed possessed teaching beliefs that were more in line with the conventional didactic instructional approach. It is posited that this is because their past experiences of learning and the kind of instruction they received during their past learning tended to be more teacher directed. When they were guided to experience more student-centered knowledge building, they were given the opportunity to make a comparison with their past learning experiences. Knowledge building thus served as a contrasting case for deeper reflection of their teaching beliefs and practice. In addition, knowledge building also allowed them to adaptively and flexibly experiment with new teaching ideas. This may be why they developed more flexible and innovative ways of teaching practices.

Moreover, the study also found that there were some advantages in using KF. Not only did it allow ideas to be preserved via the posting of teaching feedback onto the KF website, but it was also helpful for the participants to reflect and share their ideas for solving teaching-related problems any time after class in order to improve their teaching practice. Because ideas could be contributed via the instructionally designed feedback mechanism and recorded in KF, teacher-education students were more likely to spend more time outside class reflecting on their own beliefs and practice. At the same time, KF also allowed the participants to be aware of and to monitor their changing beliefs as KF kept a record of what the participants did and revised in terms of their teaching plans and methods.

Overall, the results are consistent with findings from previous knowledge-building studies (e.g., Hong and Lin 2010; Hong et al. 2011; Chai and Tan 2009) indicating that a knowledge-building pedagogy is effective in helping foster epistemological belief change. Arguably, while cultivating teachers' pedagogical content knowledge is important and should always be included as part of the teacher-education curriculum, it is also equally important to help teacher-education students develop more informed constructivist-oriented mathematics teaching beliefs as to be supported by the current education reform movement. To foster such belief change, it would be crucial to avoid traditional didactic ways of teacher preparation and to adopt more constructivist-oriented instruction in order to cultivate future teachers who can view mathematics teaching more as adaptive and constructivist-oriented, rather than routine and ritualistic, practices.

For future research, as pointed out by Clark and Peterson (1986), teaching beliefs not only have a great influence over teacher's thoughts and behavior, but they also affect classroom atmosphere and hence the effectiveness of students' learning performance (see also Ernest 1989). Further research should examine how the learning atmosphere changes due to knowledge building. Also, as a case study and because the participants in this study were all academic high achievers, the generalizability of the findings may be limited so future studies should try to include a control group and to increase the sample size and should also try to conduct studies in different educational contexts.

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