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Developing effective knowledge-building environments through constructivist teaching beliefs and technology-integration knowledge: A survey of middle-school teachers in northern Taiwan

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ABSTRACT

The creation of effective knowledge-building environments (KBEs) to help learners develop essential skills in a knowledge society has gradually been recognized as an important goal in education (see the review by Chen & Hong, 2016), but the qualities that teachers require to develop KBEs remain to be investigated. Drawing on a review of relevant literature, we hypothesized that constructivist teaching beliefs (CTBs) and technology-integration knowledge (TIK) would prove important determinants of teachers' potential to develop KBEs. The main aim of this study was to test a structural equation model encompassing teachers' CTBs and TIK, and determine whether these variables were reliable predictors of teachers' potential to develop KBEs. A convenience sample of 390 middle-school teachers was selected from northern Taiwan for this survey study. Our results allowed us to construct a path model and indicate that CTBs, which are positively mediated by TIK, facilitate teachers' potential to develop KBEs. The implications for teacher training are discussed.

1. Introduction

The design and development of learning environments can greatly affect how students learn and their learning outcomes (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Wang & Hannafin, 2005). Some types of learning environments are better at helping students to acquire fundamental knowledge and concepts specified in a curriculum whereas others may be more suitable for supporting in-depth investigation of a topic or problem with the aim of advancing knowledge (Edelson, 2001; Paavola & Hakkarainen, 2005; Quintana et al., 2004). Although helping students to acquire and master basic knowledge and concepts can be important, there is evidence that engaging them in problem-solving and in-depth inquiry is even more important, as it helps to develop their high-level thinking skills (Scardamalia & Bereiter, 2014; Scardamalia & Bereiter, 2016). Knowledge-building environments (KBEs) have been identified as particularly useful for nurturing collaboration, communication, and creativity skills (Gilbert & Driscoll, 2002; Lin, Chang, Lin, & Hong, 2017; Ryser, Beeler, & McKenzie, 1995; Scardamalia, Bransford, Kozma, & Quellmalz, 2012; Stahl, 2000; Zhang, Hong, Scardamalia, Teo, & Morley, 2011; Zhang, Scardamalia, Reeve, & Messina, 2009). Designing or fostering KBEs has, however, been regarded as a difficult pedagogical problem among teachers (Hong, Chen, Chai, & Chan, 2011). Hence the main purpose of this study was to investigate teacher factors that may affect teachers' potential to develop KBEs. As discussed below, a literature review identified teachers' constructivist teaching beliefs (CTBs) and technology-integration knowledge (TIK) as two potential such factors, and building on this review, it is posited that there are close connections between KBEs, CTBs and TIK in that TIK is likely to positively reinforce the relationship between CTBs and KBEs. Therefore, in this study we particularly carried out structural equation modeling (SEM) to test some hypotheses (see further below) concerning KBEs, CTBs, and TIK. In the following section we first discuss the essential role that KBEs will play in educating future learners and explain why CTBs and TIK may affect teachers' development of KBEs. Then we describe in detail the SEM carried out to test the hypotheses and validate the proposed hypothesized model. Finally, we report our findings and discuss their implications for teacher training and future research.

2. Literature review

2.1. Knowledge-building environments (KBEs)

Research shows that how teachers shape a learning environment

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can affect how students learn, and develop their knowledge and abilities (e.g., collaboration and communication abilities) in that environment (Eggen & Kauchak, 2007). Hong and Sullivan (2009) describe two common types of learning environments: concept-based to idea-centered. Concept-based environments assume that conceptual knowledge and factual recall are important for the acquisition of essential knowledge, whereas idea-centered environments attempt to encourage learners to work creatively with "ideas" in order to construct knowledge (Bereiter & Scardamalia, 1998; Duffy & Jonassen, 2013). In a typical concept-based learning environment teachers are an authoritative knowledge source and teach well-established concepts to learners, who are expected to acquire them systematically, so that they accumulate a rich body of fundamental knowledge. The fundamental unit of knowledge for learning under such environments is a "concept" that is clearly defined in authoritative sources such as textbooks and curriculum guidelines. Concept-based environments have been found to be an efficient tool for preparing learners for high-stake examinations. In contrast, an idea-centered environment highlights the importance of working with ideas: generation, diversification, sharing, exchange, reflection, evaluation and elaboration of ideas are used in the process of working towards an optimal solution to a problem or a challenge (Scardamalia, 2002). Instead of concepts, the basic unit of knowledge for learning is the "idea", an initial or primitive form of knowledge that can be developed or refined within the learning environment. In idea-centered environments the emergence of understanding is valued and usually occurs gradually, as a result of learning and working together on ideas.

In an effective KBE, students are required to engage in three essential activities, working with ideas, assuming agency and fostering community. First, ideas are viewed as knowledge objects and so knowledge-building activities are idea-centered (rather than concept-based); learners must see ideas as cognitive artifacts in order for a KBE to be effective (Bereiter, 2002). Moreover, knowledge-building activities have to be focusing on sustained idea-revision cycles (Hong & Sullivan, 2009; Zhang et al., 2011): ideas are generated and then gradually diversified, modified and refined so that they can be used to address authentic real-life problems. Second, in knowledge-building activities learners are treated as the subjects of knowledge and the emphasis is on self-initiated and self-directed learning, thus learners assume epistemic agency for autonomous learning, inquiry, problem-solving, and knowledge advancement and engage in constructive use of authoritative sources to support idea-centered activities (Scardamalia & Bereiter, 2006). Third, an effective KBE fosters community, because the social aspects of knowing and knowledge-building activities highlight community awareness and students are required to learn collectively, as a group, rather than individually (i.e., learning by group rather than in group). The distinction between individual learning and collective knowledge work is that the former emphasizes individual knowledge acquisition and growth whereas the latter focuses on advancing collaborative knowledge work in a community.

A review by Chen and Hong (2016) concluded that engagement in KBEs can help students develop critical knowledge skills and competencies, including graphical, reading and writing skills. Previous studies also indicate that KBEs help students to attain a deep understanding of subjects and improve their collaboration skills through group knowledge work (Van Aalst, 2006), engagement in meaningful intellectual discourse and effective communication with community members (Hewitt & Scardamalia, 1998), as well as enhancing reflective and creative thinking skills (Lin et al., 2017; So, Seah, & Toh-Heng, 2010). Building on the above discussion regarding the importance of KBEs for productive learning, below we further discuss how CTBs may affect teachers' potential to develop KBEs.

2.2. Constructivist teaching beliefs (CTBs)

Teachers' beliefs are the views they hold about teaching, learning, online environment and other less significant factors, as well as the interactions among these factors (Calderhead, 1996; Meirink, Meijer, Verloop, & Bergen, 2009; Nespor, 1987; Pajares, 1992). A growing body of evidence suggests that it is necessary to study teachers' teaching beliefs because they can have a subtle but long-term impact on their performance in classroom (Pajares, 1992; Richardson, 1996; Wilson, 1990). In particular, studies show that teachers' teaching beliefs and preferred instructional approaches influence how they design online or classroom learning environments and how they teach in these environments (Hong & Chai, 2017; Prawat, 1992).

There are several ways of categorizing teaching beliefs or views, but a commonly used distinction in most studies of teachers' teaching beliefs is based on two prototypic ideologies, (1) subject-matter or teacher-oriented beliefs and (2) constructivist-oriented beliefs (Entwistle, Skinner, Entwistle, & Orr, 2000; Meirink et al., 2009; Samuelowicz & Bain, 2001). The former is associated with a more didactic approach to teaching, whereas the latter emphasizes discovery-oriented learning. Previous studies suggest that teachers with more constructivist teaching beliefs are more likely to engage students in active and interactive learning activities, rather than passive learning behaviors and activities (Ertmer, 2005; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012).

Nevertheless, although some studies have found that CTBs are associated with a teaching style that supports student-initiated and -directed inquiry and discovery-based learning, others indicate that teachers' teaching beliefs may not always align with their classroom practice (Judson, 2006; Ravitz, Becker, & Wong, 2000). A study by Hong et al. (2011) also showed that there is some cognitive misalignment between what teachers believe they ought to do in the classroom and what they believe they can actually do. Thus it remains unclear whether teachers who hold more constructivist teaching beliefs do actually engage in constructivist teaching practices. It is also necessary to further test whether teachers embracing constructivist-oriented teaching beliefs could help to develop KBEs. An aim of this study, therefore, was to investigate the extent to which CTBs account for variance in teachers' potential to develop KBEs.

Teachers' teaching beliefs are, however, only one of the factors that may influence teachers' ability to develop KBEs; other factors may also be relevant, there is empirical evidence that TIK may be such a factor (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010; Polly, Mims, Shepherd, & Inan, 2010). This is plausible because teachers' teaching beliefs have been found to be associated with technological pedagogical content knowledge (TPACK) relevant to the creation of technology-enhanced and learner-centered learning environments (Harris & Hofer, 2011).

Beliefs and knowledge have something in common. While knowledge is commonly referred as facts or truths, it can also be seen as a set of best-justified beliefs (that can be further falsified or confirmed) (Sartwell, 1991). It therefore seems worthwhile to investigate their relationships, particularly from an instructional perspective the relationships between teachers' constructivist teaching beliefs and their knowledge of how to integrate technology into teaching and design effective learning environments of KBEs. Particularly, we are interested in exploring whether the interaction between teachers' teaching beliefs and technology-Integration Knowledge is related to their potential to foster environments that will help learners learn better (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). As such, we move further to discuss the nature of technology-Integration Knowledge.

2.3. Technology-integration knowledge (TIK)

The introduction of information and communication technology (ICT) to education has increased access to good education and technology-assisted learning (Aldunate & Nussbaum, 2013; Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Archambault & Barnett, 2010; Bell, Urhahne, Schanze, & Ploetzner, 2010; Bereiter, 2002; Bereiter &

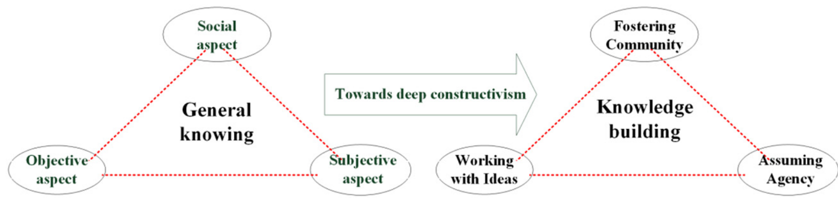

Fig. 1. A conceptual framework of knowledge development from general constructivist knowing to deep constructivist knowledge-building.

Scardamalia, 1998; Bower, 2008; Calderhead, 1996; Chai, Hong, & Teo, 2009; Chai, Koh, & Tsai, 2010; Bower, 2008; Vrasidas, 2015; Yeung, Taylor, Hui, Lam-Chiang, & Low, 2012). Teachers are encouraged to integrate technology into their teaching and to shape a more supportive, technology-enhanced learning environment for students. Effective technology integration, however, requires investment of time and effort and can only take place in the context of an appropriate curriculum and instructional design. Hew and Brush (2007) reviewed studies from 1995 to 2006 and found many challenges or barriers to integration of technology into curricula and instruction (e.g., resources, institutional culture, attitudes and beliefs, knowledge and skills, assessment, and so on). Harris, Mishra, and Koehler (2009) found that integration of technology into instruction involves not merely bringing new educational technologies into class; it is important to take into consideration students' needs in relation to the material to be taught and the pedagogy teachers are to implement (Harris et al., 2009). Whether and how teachers are able to integrate technology into their classroom teaching practice systematically or to use technology to create a better learning environment is also influenced by their beliefs and attitude to the use of technology in teaching and education (Ottenbreit-Leftwich et al., 2010; Palak & Walls, 2009; Watson, 2006).

Koehler and Mishra (2005) proposed a conceptual framework of technological pedagogical content knowledge (TPACK) to help teachers develop their knowledge and skills with regard to integration of technology into teaching. The TPACK framework adds a technology component to Shulman's (1986) well-known theoretical framing of teachers' pedagogical content knowledge. TPACK represents seven types of knowledge teachers need to design, implement and evaluate a curriculum and approach to instruction: content knowledge (CK), pedagogical knowledge (PK), technology knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). The TPACK framework treats knowledge about how technology can be integrated into teaching (what we refer to as TIK) as an important aspect of teachers' professional expertise, due to the rapid development of new teaching and learning technologies in education. In particular, the TPACK framework recognizes four types of teaching knowledge related to use of technology: TK, TPK, TCK and TPCK. These four types of teaching knowledge are essential to teachers' ability to integrate technology effectively into their teaching and design better technology-enhanced learning environments (Koehler, Mishra, & Yahya, 2007; Messina & Tabone, 2012; Mishra & Koehler, 2006).

A TPACK-related review by Voogt et al. (2013) notes that there have been many studies validating the TPACK model and examining the relationships between TPACK and other variables (such as teacher variables, student variables, curricular content, general pedagogy variables, technology variables, and learning-context variables). In particular, the holistic TPACK framework has been widely adopted in analyses of the development of teachers' professional knowledge, based on quantitative methods such as surveys (e.g., see Chai, Koh, & Tsai, 2010; Chai, Koh, Tsai, & Tan, 2011; Koh, Chai, & Tsai, 2010; Schmidt et al., 2009) and qualitative methods such as case studies (e.g., see Lim & Chai, 2008). Other studies have tested or validated the TPACK framework in samples of both pre-service and in-service teachers (Archambault & Barnett, 2010; Chai et al., 2011; Jimoyiannis, 2010; Liang, Chai, Koh, Yang, & Tsai, 2013; Messina & Tabone, 2012; Schmidt et al., 2009). For example, Chai, Koh, and Tsai (2013) develop and validate a TPACK efficacy survey for Asian pre-service teachers. Chen and Jang (2014) looked into how teachers' TPACK is related to the stages of their pedagogical concerns and found that the higher the level of teachers' technology integration, the more likely they are to develop synthesized types of TPACK knowledge. Other studies also suggest that teachers with more learner-centered pedagogical beliefs tended to be better at integrating technology into teaching, and that doing so tended to enhance their TPACK-related design skills (Tsai & Chai, 2012). Moreover, studies have examined the relationships between teacher's TPACK and demographic factors (Lee & Tsai, 2010), such as gender (Koh et al., 2010) and teaching experience (Jang & Tsai, 2013; Koh, Woo, & Lim, 2013), particularly among in-service teachers (Koh et al., 2010). Nevertheless, although the complete TPACK framework has been employed and investigated in various studies, no studies have investigated the nature and role of TIK (as defined to be a combination of TK, TCK, TPK, and TPCK; see Koh & Divaharan, 2011) in relation to teachers' potential to foster knowledge-building environments (KBEs; Chen & Hong, 2016).

2.4. Relationships among KBE, CTB, and TIK: research questions and hypotheses

As Fig. 1 shows, building on René Descartes' conceptualization, the object of knowing (e.g., knowledge concepts in a textbook), the subject of knowing (e.g., the learner), and the related social factors (e.g., people or knowledge interactions), allow the three basic aspects of general constructivist knowing to take place. To further transform general knowing or learning into more in-depth knowledge-building or creating, however, it is essential to translate the above conceptual framework into one that values ideas as object of inquiry (or building blocks for advancing knowledge), agents as subject of inquiry (or knowledge workers), and community as social venue for collaborative idea improvement.

Building on the above literature review on KBE, CTB, and TIK, it is reasonable to posit that this transformation from general constructivist knowing to deep constructivist knowledge-building in Fig. 1 would progressively require teachers to embrace a stronger CTB. More importantly, as acknowledged in the Cambridge Handbook of the Learning Sciences to be one of five foundational constructivist approaches (Saywer, 2014), knowledge building calls for deep constructivism (Scardamalia, 2002), which is seen as radically different from most of what goes on in the name of teaching for understanding and constructivism (Bereiter, 2002). Knowledge building by nature is principle-based rather than procedure-based. As such, it highlights the importance of teachers engaging in fairly flexible and adaptive pedagogical enactment using a set of knowledge-building principles as heuristics (see Scardamalia, 2002, for details), with an aim to continually improve classroom designs and practices (Chan, 2011; Hong, Chen, & Chai, 2016). This is in contrast to other constructivist approaches that are defined by structured learning procedures, e.g., inquiry learning cycles (Bell, Urhahne, Schanze, & Ploetzner, 2010; Pedaste et al., 2015), or scripted learning activities (Mäkitalo, Weinberger, Häkkinen, Järvelä, & Fischer, 2005; Stegmann, Wecker, Weinberger, & Fischer, 2012). Therefore, it is also plausible to posit that general constructivist teaching beliefs (CTBs) alone, although necessary, may not be sufficient to help teachers transform typical classrooms into knowledge building environments (KBEs) that highlight deep constructivism. TIK which values integrating technology into class teaching, however, as elaborated above, can be seen as a set of best-justified beliefs to serve as an important mediating role in strengthening the presumably positive relationship between CTBs and KBEs. Previous studies have also demonstrated that teachers with CTBs are more likely to support integration of technology into classroom activities (Ertmer, 2005; Ertmer et al., 2012). In other words, CTBs appear to be linked to TIK to help teachers foster the development of KBEs. Hence, in this study, we would like to propose a model of the relationships linking the three discussed factors, with our main research question formulated as follows: Is the proposed SEM model valid and fit well with the data collected? The three main hypotheses linking to this model are as follows:

H1. CTB has a direct and positive effect on teachers' perceived potential to develop a KBE.

H2a. CTB has a direct and positive effect on teachers' TIK, and TIK which in turn has a direct and positive effect on teachers' perceived potential to develop a KBE."

H2b. The association between CTB and KBE is moderated by the level of participants' TIK.

Furthermore, to better understand the nature of, and the relationships among, the three variables of KBE, CTB, and TIK, within the specific context of educational reform in Taiwan, this study also tried to utilize the demographical data to statistically analyze (1) how the participating teachers perceive their potential to foster a KBE in terms of working with ideas, assuming agency, and fostering community; (2) the overall level of Taiwanese teachers' CTBs; and (3) the extent of teachers' TIKs in terms of demographic variables (including gender, teaching experience, and experience in using learning platforms).

3. Method

3.1. Context and participants

This study is situated in the context of the ongoing Taiwanese educational reform, which focuses on helping teachers develop ICT skills and improve ICT integration proficiency. This will allow them to become more adaptive and creative teachers able to help learners develop the much needed knowledge skills that are essential to a knowledge society. To this end, it is expected that teachers need to assume the role of a change agent with an aim to progressively transforming their classroom environments into KBEs.

As for participants, we recruited a convenience sample of 550 teachers, and 390 of them answered our survey. There was 70.9% effective questionnaires. The participation in the study was voluntary and, in accordance with human subject principles, an informed consent was taken from the subjects before their enrollment in this study. The participants were middle-school teachers in northern Taiwan who agreed to take part in the study, 66.7% were female and 33.3% were male. The characteristics of the sample are presented in Table 1.

Table 1
Description of background information of all participants in CFA analysis.

Factors	Items	All participants
Gender	Male	33.6%
	Female	66.4%
Years of teaching	≤10 years	50.5%
	> 10 years	49.5%
Use of learning platform in teaching	No	53.6%
	Yes	46.4%

3.2. Measures

The survey comprising questions on demographics and three scales for measuring in-service teachers' perspectives of learning environment, teaching belief and technology-integrated knowledge.

The first section of the measures comprised questions about the demographic situation of the respondents (gender, age, educational level, teaching experiences, and experiences of using instructional technology. The second section of the survey consisted of three subscales: KBEs, CTB and TIK, using five-point Likert scales, ranging from 1 to 5, with higher scores indicating a higher rating of self-reported CTBs and TIK. The survey was partly based on existing scales.

3.2.1. Knowledge-building environment scale (KBE)

The survey items, used to assess teachers' potential ability to develop KBEs, were drawn from a 24-item scale developed by Lin, Hong, and Chai (2014). Their scale was organized into three subscales: (1) working with ideas (e.g., "In this course, it is important to embrace divergent ideas"); (2) assuming agency (e.g., "In this course, students are always reflecting on how to improve knowledge"); (3) fostering community (e.g., "In this course contributing to the community's learning and growth is important") (Lin et al., 2014). Reliability of KBES scale in previous study was 0.95 (Lin et al., 2014). Lin et al.'s (2014) original scale and items were developed for a sample of university students, not for teachers. In the current study we surveyed how teachers perceive the environment.

3.2.2. Constructivist teaching belief (CTB)

To assess teachers' CTBs, Chan and Elliott (2004, p. 826) developed a "conceptions about teaching and learning" survey to assess Hong Kong pre-service teachers' teaching beliefs. Later, this survey was modified by Chai, Hong, and Teo (2009) for specific use among Taiwanese pre-service teachers. In the present study, we adopted Chai, Hong, and Teo's modified scale and used the following items: (1) learning means students have ample opportunities to explore, discuss, and express their ideas; (2) instruction should be flexible enough to accommodate individual differences among students; (3) effective teaching encourages more discussion and hands-on activities for students; (4) the focus of teaching is to help students construct knowledge from their learning experience instead of knowledge communication.

3.2.3. Technology-integrated knowledge (TIK)

Building on Koh and Divaharan's (2011) conceptualization of TIK, TIK is framed as containing items adopted from Koh, Chai, and Tsai (2013), for instance: (1) TK (e.g., I have the technical skills to use computers effectively."); (2) TCK (e.g., "I know about the technologies that l have to use for the research of content of my teaching subject"); (3) TPK (e.g., "I am able to facilitate my students to use technology to construct different forms of knowledge representation."); (4) TPCK (e.g., "I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.") Mean scores were used for each respondent in the survey.

3.3. Procedure

Before the actual study, to ensure the quality of the survey, a pilot study was conducted by collecting data from 59 middle-school teachers in northern Taiwan. Cronbach's alpha coefficient for scales ranged from 0.81 to 0.91, with specific alpha values for CBT, TK, TPK, TCK, TPCK, working with ideas, assuming agency, and fostering community as follows: 0.819, 0.872, 0.861, 0.834, 0.894, 0.817, 0.892, and 0.912.

Then, for the actual administration of the survey, data were collected from 28 junior high schools in northern Taiwan. The junior high schools' 550 teachers were invited to complete the questionnaire. In the end, only 390 teachers took part in the final survey.

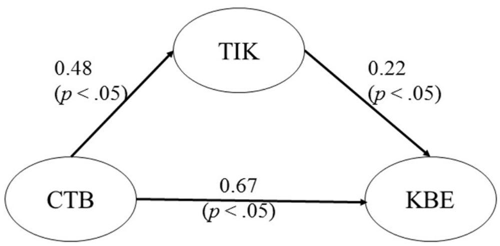

Fig. 2. The structural model.

3.4. Analytical strategy

First, descriptive statistics were conducted using SPSS 21.0 and R 3.1.2 to explore the items of the questionnaire. Multivariate normality was also checked using Mardia's coefficient of multivariate kurtosis.

Eight constructs were first established through internal reliability, Cronbach alphas, for all constructs: CTB ($\alpha = 0.82$), Working with Idea ($\alpha = 0.85$), Assuming Agency ($\alpha = 0.89$), Fostering Community ($\alpha = 0.91$), TK ($\alpha = 0.86$), TPK ($\alpha = 0.88$), TCK ($\alpha = 0.73$), TPCK ($\alpha = 0.79$). A measurement model was specified in LISREL8.72 with the eight latent constructs (CTB, Working with Idea, Assuming Agency, Fostering Community, TK, TPK, TCK, and TPCK) that contain 44 survey items for measurement.

Following confirmation of the measurement model, the test statistics and goodness-of-fit indices to assess the adequacy of the model, the structural model outlined in Fig. 2 was then specified in LISREL 8.72. After establishing goodness fit of current model, path coefficients were analyzed to test our hypotheses.

Next, we tested the moderation effect of TIK on the relationship between CTB and KBE. The latent variable interaction between TIK and CTB was constructed using the Latent Moderated Structural Equation (LMS) approach (Marsh, Wen, Hau, & Nagengast, 2006) by Mplus (Muthén & Muthén, 2012). Standardized coefficients were calculated with the method proposed by Maslowsky, Jager, and Hemken (2014) along with the LMS method.

Last, to better understand the nature of KBE, CTB, and TIK within a Taiwanese teaching context, we further employed simple *t*-tests to (1) examine how teachers see the importance of the three essential KBE activities (i.e., working with ideas, assuming agency, and fostering community), (2) report Taiwanese teachers' CTB level, and (3) compare teacher's TIK level in terms of demographical variables (i.e., gender, service years, and use of learning platform).

4. Results

4.1. Descriptive statistics

Before testing the three hypotheses, we conducted CFA to construct validity of current scale. Firstly, we analyzed data and found no evidence of notable non-normality, using Kline's (2005) criteria that values of skewness (−0.23 to 0.17) and kurtosis (−0.38 to 0.14) should not exceed |3| and |10| respectively. Initial inspection of the data revealed that the Mardia coefficient was significant (Kurtosis $z = 1.83$, $p = .067$), indicating that the data have multivariate normality. Table 2 provides description of subscales in the model. The subscale means were between 3.02 and 3.68, and standard deviations between 0.60 and 0.89. We then used R (version 3.1.2) and the R package "psych" to analyze items in subscales to obtain ordinal alpha values, and these values were between 0.63 and 0.93.

4.2. Test of the measurement model and structural model

In this section, we first test H1 and H2a. LISREL was conducted to assess the factor loadings of items to the measurement model; the standardized factor loadings are range from 0.66 to 0.88, and the *t*-values range from 13.61 to 17.29 ($p < .05$). Previous researchers have argued that multiple indices should be used to examine model fit (e.g., Hair, Black, Babin, Anderson, & Tatham, 2010; Kline, 2005), so we used a variety of indices to obtain a comprehensive picture of model fit. We applied commonly used criteria for satisfactory model fit (given in parentheses): ξ^2/df = 1.82 (< 5.0); RMSEA = 0.062 (< 0.08); SRMR = 0.039 (< 0.08); CFI = 0.94 (> 0.90); NNFI (also called the Tucker-Lewis index) = 0.97 (> 0.90). The corresponding statistics for the sample as a whole were as follows: χ^2/df = 3.74; RMSEA = 0.080; SRMR = 0.047; CFI = 0.97; NNFI = 0.96. There was evidence to suggest that the eight subscales were appropriate for assessing the three

Table 2
The overall data description for each item.

	All				
Items	M	SD	Skewness	Kurtosis	Ordinal alpha
Working with idea	3.67	0.64			
IDEA1	3.56	0.91	-−0.32	−0.20	0.89
IDEA2	3.78	0.79	−0.49	0.46	0.85
IDEA3	3.59	0.84	−0.34	−0.12	0.86
IDEA4	3.72	0.82	−0.43	0.15	0.86
IDEA5	3.79	0.83	−0.23	−0.43	0.86
IDEA6	3.58	0.87	−0.19	−0.31	0.86
Assuming agency	3.20	0.73			
AGENCY1	2.95	1.00	0.22	−0.47	0.90
AGENCY 2	2.92	1.03	0.10	−0.55	0.90
AGENCY 3	2.97	1.03	0.04	−0.51	0.89
AGENCY 4	3.55	0.88	−0.21	−0.35	0.91
AGENCY 5	3.38	0.88	−0.24	−0.05	0.90
AGENCY 6	3.24	1.00	−0.09	−0.43	0.90
AGENCY 7	3.17	0.98	−0.11	−0.53	0.89
AGENCY 8	3.40	0.90	−0.32	−0.09	0.91
Fostering community	3.36	0.72			
COMMUNITY1	3.39	0.97	−0.30	−0.32	0.92
COMMUNITY2	3.20	0.90	0.00	−0.41	0.92
COMMUNITY3	3.40	0.94	−0.07	−0.31	0.92
COMMUNITY4	3.43	1.00	−0.12	−0.67	0.92
COMMUNITY5	3.37	0.93	−0.13	−0.22	0.92
COMMUNITY6	3.29	0.97	−0.22	−0.39	0.92
COMMUNITY7	3.35	0.93	−0.12	−0.35	0.92
COMMUNITY8	3.34	0.96	−0.11	−0.38	0.92
COMMUNITY9	3.48	0.91	−0.13	−0.36	0.93
Constructivist teaching belief	3.47	0.73			
BELIEF1	3.43	0.95	−0.35	−0.20	0.79
BELIEF2	3.40	0.89	−0.26	0.00	0.81
BELIEF3	3.50	0.90	−0.35	−0.24	0.81
BELIEF4	3.55	0.89	−0.41	−0.01	0.84
TK	3.30	0.78			
TK1	3.63	0.90	−0.54	0.34	0.88
TK2	3.56	0.93	−0.35	−0.08	0.87
TK3	3.45	0.90	−0.31	−0.15	0.87
TK4	3.36	0.94	−0.20	−0.23	0.87
TK5	2.88	1.16	0.10	−0.82	0.91
TK6	2.89	1.17	0.12	−0.82	0.91
TPK	3.29	0.82			
TPK1	3.43	1.00	−0.29	−0.38	0.89
TPK2	3.49	0.98	−0.33	−0.40	0.89
TPK3	3.19	1.01	−0.17	−0.39	0.86
TPK4	3.20	0.99	−0.20	−0.34	0.87
TPK5	3.12	1.02	−0.08	−0.54	0.89
TCK	3.05	0.86			
TCK1	2.52	1.18	0.29	−0.82	0.87
TCK2	3.23	1.13	−0.25	−0.69	0.80
TCK3	3.37	0.99	−0.50	−0.04	0.77
TCK4	3.06	1.00	−0.11	−0.36	0.77
TPCK	3.02	0.86			
TPCK1	2.85	1.08	0.07	−0.51	0.89
TPCK2	3.33	1.03	−0.38	−0.31	0.91
TPCK3	2.99	1.08	−0.11	−0.56	0.89
TPCK4	2.76	1.14	0.11	−0.76	0.90
TPCK5	2.99	1.07	−0.06	−0.66	0.89
TPCK6	3.19	1.02	−0.20	−0.37	0.90

Table 3
Reliability and validity of the subscales for TIK, KBE, and CTB.

		α	CR	AVE
KBE	1. Working with idea	0.84	0.88	0.55
	2. Assuming agency	0.91	0.92	0.59
	3. Fostering community	0.93	0.93	0.60
CTB	4. Constructivist teaching belief	0.84	0.87	0.63
TIK	5. TK	0.90	0.91	0.62
	6. TPK	0.90	0.91	0.67
	7. TCK	0.85	0.88	0.66
	8. TPCK	0.92	0.92	0.67

Note: CR = Construct Reliability, AVE is ≥0.50 is acceptable; AVE = Average Variance Extracted, CR ≥ 0.70 is acceptable (Nunnally & Bernstein, 1994).

variables in the proposed model (CTBs; TIK; self-perception of building KBEs) and that the variables were correlated but distinct from one another. The standardized path coefficients of the structural model were established (i.e., $\beta_{CTB \rightarrow TIK} = 0.48$, $p < .05$, $\beta_{CTB \rightarrow KBE} = 0.67$, $p < .05$, and $\beta_{TIK \rightarrow KBE} = 0.22$, $p < .05$) (see Fig. 2). Reliability and validity statistics for data from the whole sample also provided support for the model.

As shown in Table 3, the values of ordinal alpha and construct reliability were > 0.70 and the factor loadings and the average variance extracted (AVE) were > 0.50, indicating satisfactory composite reliability and convergent validity (see Hair et al., 2010). Moreover, all of the square roots of AVEs were larger than off-diagonal elements in the corresponding rows and columns (see Table 4), suggesting that the instruments have adequate discriminant validity.

Table 4 shows that the AVE (i.e., discriminant validity) can be regarded as adequate, since the square root of AVE is larger than the inter-construct correlations (Fornell, Tellis, & Zinkhan, 1982), signifying that discriminant validity at the construct level was adequate in this sample.

4.3. Testing for TIK as a moderator

In order to test if participants' TIK would moderate the relationship between CTB and KBE (H2b), we constructed the latent interaction between TIK and CTB using Mplus (Muthén & Muthén, 2012). The result showed the latent interaction term between TIK and CTB was not statistically significant in predicting KBE (β = 0.064, $p = .197$). CTB and TIK were significant in predicting KBE, $\beta_{CTB \rightarrow KBE}$ was 0.635 ($p < .001$) and $\beta_{TIK \rightarrow KBE}$ was 0.216 ($p < .001$) (see Fig. 3). Therefore, H2b was rejected.

4.4. Additional analyses of the nature of KBE, CTB, and TIK within the Taiwanese teaching context

First, we conducted paired *t*-tests to better understand how the participating teachers perceive their potential to foster a KBE in terms of KBE's three core activities, including working with ideas, assuming agency, and fostering community. In order to avoid the inflated Type I error rate, Bonferroni correction was applied by setting the nominal alpha at 0.015. We found that, of the three essential activities required in a KBE, the perceived potential among teachers to foster a knowledge-building environment are: working with ideas ($M = 3.70$, $SD = 0.60$), fostering community ($M = 3.36$, $SD = 0.72$), and students' assuming agency ($M = 3.19$, $SD = 0.93$) (see Table 5). Overall, teachers tend to think that, as compared with working with ideas and fostering community in a KBE, it is relatively more difficult and challenging to help students assume agency, because assuming agency means that students need to shoulder the full responsibility of dealing with the problems of goals, self-evaluation, self-motivation, long-range planning, etc. However, these responsibilities are usually managed by teachers rather than students. This may be the main reason that teachers consider guiding students to assume agency is pedagogically challenging.

Second, it was found that the mean CTB rating ($M = 3.47$; $SD = 0.73$) was higher than the mid-point of the scale (3) out of 1–5 Likert scale, indicating that the participating teachers were generally inclined towards constructivist beliefs. This finding is similar to the findings of two previous studies of Taiwanese teachers, which also found that teachers generally possess positive CTBs (Chai et al., 2009; Hong & Lin, 2010). Teachers' mean CTB rating was higher than their TIK ($M = 3.22$, $SD = 0.71$, with all four dimensions combined) ($t = 6.29$, $p < .001$; paired-samples *t*-test), implying that although they held fairly strong CTBs they lacked the TIK to implement them.

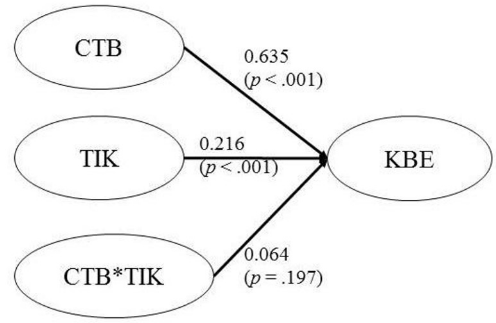

Fig. 3. The moderation model.

Table 5
Comparison of the three essential activities required in a KBE using a paired *t*-test.

V1 vs. V2	V1 mean (SD)	V2 mean (SD)	T value
WI vs. AA	3.70 (0.60)	3.19 (0.93)	15.23***
AA vs. FC	3.19 (0.93)	3.36 (0.72)	−5.80***
FC vs. WI	3.36 (0.72)	3.70 (0.60)	−10.83***

Note: WI means working with ideas; AA means assuming agency; and FC means fostering community.
*** $p < .001$.

Table 4
Correlations among and discriminant validity of the eight subscales.

	1	2	3	4	5	6	7	8
1. Working with idea	(0.75)							
2. Assuming agency	0.60**	(0.75)						
3. Fostering community	0.63**	0.71**	(0.77)					
4. Constructivist teaching belief	0.61**	0.55**	0.57**	(0.81)				
5. TK	0.28**	0.24**	0.32**	0.31**	(0.79)			
6. TPK	0.37**	0.42**	0.48**	0.44**	0.64**	(0.82)		
7. TCK	0.22**	0.29**	0.34**	0.29**	0.63**	0.72**	(0.81)	
8. TPCK	0.28**	0.42**	0.44**	0.37**	0.54**	0.75**	0.79**	(0.81)

Note 1: **$p < .01$. Note 2: All correlations (off-diagonal figures) are significant at the 0.01 level; diagonal figures in the parentheses are the square root of average variance extracted (AVE) from items.

Table 6
Teacher's technology-integration knowledge (TIK) by gender, service years, and platform use.

	Gender			Service years			Use of platform		
	Male (n = 131)	Female (n = 259)	*t*	≤10 years (n = 197)	> 10 years (n = 193)	*t*	Yes (n = 180)	No (n = 210)	*t*
TIK	3.28 (0.71)	3.10 (0.72)	2.38*	3.27 (0.66)	3.06 (0.77)	2.90**	3.37 (0.70)	2.98 (0.70)	5.45***

* $p < .05$.
** $p < .01$.
*** pTable 1, 2, 3, 4, 5 and 6 < .001.

There is still room for improvement in their TIK.

In descending order, scores for the four different types of TIK were as follows: (a) TK ($M = 3.30$, $SD = 0.78$); (b) TPK ($M = 3.29$, $SD = 0.82$); (c) TCK ($M = 3.05$, $SD = 0.86$); (d) TPCK ($M = 3.02$, $SD = 0.86$). An omnibus test revealed differences among the four TIK dimensions ($F(2.65, 388.06) = 102.37$, $p < .001$; Greenhouse-Geisser correction applied as above) and post hoc pairwise comparisons confirmed differences between the following pairs: TK > TPK, TK > TCK, TK > TPCK, TPK > TCK, and TPK > TPCK. This implies that teachers possess more general technological knowledge than other types of TPACK knowledge, and they also tend to know more about using technology to enhance their teaching (i.e., TPK) than they do about using it to deliver content (i.e., TCK) or to align their teaching style to the content (i.e., TPCK).

Moreover, there were differences in TIK related to gender, teaching experience and use of a learning management system (see Table 6). Male teachers had more TIK than female teachers and young teachers (with < 10 years of teaching experiences) had more TIK than veteran teachers. Finally, teachers who had access to learning platforms tended to have better TIK than those without, indicating that generally it would help enhance teachers' TIK by encouraging them to employ learning platforms in their teaching practices.

5. Discussion and implications

This study explored and tested a three-variable model linking teachers' CTBs, TIK and development of KBEs that support inquiry-based and creative learning. The results indicated that this model can be applied to middle-school teachers in Taiwan. We showed that teachers who held stronger constructivist teaching beliefs were better able to develop a KBE to support creative learning, especially when such beliefs were supported by high TIK. Previous studies show that teachers' beliefs are related to the extent to which they integrate technology into their teaching (Lim & Chai, 2008; Overbay, Patterson, Vasu, & Grable, 2010). Our path analysis further suggests that there is a relationship between these two factors. Moreover, a theoretical review by Chen and Hong (2016) suggested that these two factors might be related to the development of effective KBEs. Our study also indicates that both factors can account for a considerable proportion of variance in teacher's ability to develop KBEs.

Detailed analyses of KBE development, CTBs and TIK showed that teachers tend to regard the development of KBEs as a very important way of supporting the development of collaboration, communication, and creativity skills that are essential to success in the knowledge era, but they also regard incorporating KBE development into their teaching as a very challenging prospect. In other words, there is an important discrepancy between what teachers think they should do and what they actually feel capable of doing with regard to KBE development. Recognizing that something is important does not mean that one is willing to take a risk and give it a try. This issue could be addressed by making changes to how teachers are trained as soon as possible, so that prospective teachers are better prepared to deal with new pedagogical challenges and technological innovations. Our findings also indicate that teachers tend to think that, of the three principles critical to KBE development (i.e., working with ideas, assuming agency and fostering community), assuming agency (e.g., helping students become more autonomous learners) presents the greatest pedagogical challenge. This may have to do with the high-stake examination culture in Taiwan, which has made passive learning common practice in the Taiwanese education system. Teachers' lack of confidence in their ability to help students to assume agency is another key issue that should be tackled in teacher training programs.

We found that our sample of teachers strongly endorsed CTBs. This is helpful, as there is evidence that teachers' beliefs influence their attitude to the integration of technology into pedagogical design (Chai et al., 2011; Ertmer, 2005; Ertmer et al., 2012; Hermans, Tondeur, van Braak, & Valcke, 2008; Mishra & Koehler, 2006; Sang, Valcke, van Braak, Tondeur, & Zhu, 2011). This finding also corroborates previous research indicating that there is a relationship between teachers' beliefs and use of technology in teaching (see Guzman & Nussbaum, 2009 for a review) and that teachers' TIK could be influenced by their constructivist beliefs (Mama & Hennessy, 2013). However, even if teachers endorse a constructivist approach to teaching, putting that into practice by incorporating technology into classroom teaching requires that they feel comfortable using technology and confident that they can use it to solve problems (McCain, 2005; Means & Olson, 1997). Systematic changes to the curricula of teacher training programs are required to ensure that teachers gradually acquire the TIK required to support constructivist teaching practice.

We make three observations about TIK. (1) First, there is a gender difference in teachers' TIK, with male teachers tending to possess greater TIK than female teachers. This result corroborates earlier research showing that there is gender difference in TIK among pre-service teachers (Koh et al., 2010) and a gender difference in STEM teachers' perceived TPACK (Erdogan & Sahin, 2010; Jang & Tsai, 2013). (2) Second, we found that less experienced young teachers are more knowledgeable about integration of technology into teaching than veteran teachers. A possible explanation for this is that the less experienced teachers are "digital natives" (a term generally applied to people born since 1990; Prensky, 2001) who gained more experience of technology during their own education and are thus more ready to embrace technology in the use of their teaching. (3) Third, because the Taiwanese government is promoting the use of learning management systems they are probably the most commonly used form of technology in middle schools. Only 46.4% of the teachers in our study used a learning management system in their teaching, but this group tended to have higher TIK. The message this result holds for policy-makers is that it is worth continuing to promote free use of these platforms in middle schools.

This study has some implications for the training and continuing professional development of teachers. In a knowledge-based society having the ability to acquire and create knowledge using advanced technology via shared online environments opens up new learning opportunities. Teacher educators need to ensure that teachers have the relevant beliefs, commitment and technological know-how to facilitate instructional design and assessment. Having rich knowledge of how to integrate technology into teaching is necessary but not sufficient. For example, knowing how to make good use of video technology to assist lecturing in class (i.e., a type of TIK) may only help students reproduce existing (rather than producing new) knowledge. Suck TIK needs to be further processed and transformed (e.g., asking students to work in group to find a good video clip that helps explain a concept) in order to foster knowledge-building or -creating activities that require students to assume epistemic agency and function as autonomous learners (Scardamalia & Bereiter, 2014). Moreover, integrated use of technology in KBEs involves more than just providing tools; a powerful technological integration environment is necessary to facilitate collective knowledge advancement, rather than just personal knowledge growth (Hakkarainen, 2009). To this end, teacher educator need to think further about how to improve teachers' teaching knowledge and capacity so that they can help foster KBEs and communities for their students.

This study has limitations. First, other studies have demonstrated that teachers can hold a mix of beliefs (Teo, Chai, Hung, & Lee, 2008). Depending on the nature of different teaching challenges, teaching contexts, levels of student understanding, etc., teachers may perform different instructional strategies that are supported by different teaching beliefs. Similarly, a dichotomy of concept-based vs. idea-centered environments was set up in the present study for methodological convenience. So readers are advised to exercise caution in the interpretation and application of the findings. Second, this study does not look into the predictive validity of the factors with variables or scales other than the one investigated. We acknowledge this as a limitation of this study. Further studies are advised to consider this factor when using this study's survey. Finally, it is acknowledged that a rater effect (Van Velsor, Taylor, & Leslie, 1993) may exist as rater bias (i.e., an inaccurate distortion of a judgment) can be an issue in this study when teachers are reviewing their own teaching performance with unconscious prejudice. Further studies can use replication of our results using other research methods, such as observational or interview techniques to provide corroboration of the proposed model. But even without this additional evidence, our results contribute to the evidence of causal relationships linking CTBs, teachers' TIK, and their development of KBEs.

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