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Fostering a collaborative and creative climate in a college class through idea-centered knowledge-building

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Abstract This study explored the effects of student engagement in a knowledge-building (KB) environment on their collaborative learning process and the perceived creative climate of that environment. The participants were 30 college students who undertook a living technology course in which KB were employed. The main data sources include students' online discourse and a creative climate questionnaire. The findings indicate that the students became progressively more collaborative and productive over time, and they also tended to perceive the climate of the learning environment as highly supportive of knowledge creation. Implications for designing creative learning environments are discussed.

Keywords Knowledge building · Knowledge creation · Creative climate · Computer supported collaborative learning (CSCL)

Introduction

In a knowledge-based society, the capacity for knowledge creation has become a critical factor for productive organizations of all kinds (David and Foray 2003; Drucker 1968; Florida 2002; Homer-Dixon 2006; United Nations Educational, Scientific and Cultural Organization (UNESCO) 2005). As such, many recent calls for educational reform have highlighted the importance of fostering knowledge creation and collaboration skills among learners and of transforming schools into knowledge-creating organizations or communities (Bereiter and Scardamalia 2003; Hargreaves 1999; Sawyer 2006a, b, 2007; Scardamalia and

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Bereiter 1999). Accordingly, this change has also transformed our perception of learning, from merely a means of knowledge accumulation and participation (Sfard 1998) to a means of knowledge creation (Bereiter and Scardamalia 2003; Hong and Sullivan 2009; Scardamalia 2002). However, while the argument for valuing collaborative knowledge creation as an important solution to twenty first-century education is well justified, it remains unclear what constitutes an effective learning environment which will support collaborative knowledge creation and how to design course instruction in order to cultivate such an environment (Hong et al. 2010; Hong and Sullivan 2009; Chai and Tan 2009; Scardamalia and Bereiter 2006). In order to address this question, this study examined student engagement in a knowledge-building (KB) environment and whether such engagement helped to foster a more collaborative and creative learning process and environment. In the following sections, a review of the literature on creative climates in organizations will be presented; this will be followed by a discussion of the rationale and design characteristics of a KB environment in support of knowledge creation. The focus of review on organizations is mainly because knowledge building and innovation in business or research organizations is fairly common and has been practiced for a long time, whereas, interest in knowledge building and innovation in school organizations has just started to grow (Bereiter and Scardamalia 2003; Hargreaves 1999; Hong et al. 2010).

Creative climate in organizations

As evidenced throughout history, innovations are often derived from collaborative knowledge networks, rather than individual efforts (Gloor 2006; Thagard 1997). Innovation may come from the development of so-called "little-c" (everyday) creativity (Beghetto and Kaufman 2007), e.g., ideas derived from improvised conversations between colleagues in the workplace (Sawyer 2007) or within a discussion forum (Scardamalia and Bereiter 1994). Alternatively, it may come from the development of so-called "big-C" (eminent) creativity, e.g., the invention of a new medicine or some breakthrough in the advancement of scientific theory in a research of science community. Little-c and big-C creativity are, however, closely related. A well-known example of an invention which was derived from synthesizing a great deal of little-c creativity to eventually produce a breakthrough big-C is the invention of the aircraft by the Wright brothers, who brought together many small ideas (e.g., bicycles) from their predecessors and eventually came up with the significant innovation of an aircraft. This creative process was a social one, as it consisted of a collection of ideas derived from many people's efforts through a sustained design and re-design process, as well as repeated trials and errors.

In a knowledge-based economy, collaborative networks have become the norm for teamwork. In the past, the concept of teamwork highlighted cooperation and the division of labor (Slavin 1980). Today, the concept of teamwork emphasizes creative collaboration (Hong 2011; Sawyer 2007), group cognition (Stahl 2006) and collaborative KB (Scardamalia 2002). Corporate cultures have begun to realize the power of collaborative innovative teamwork (Gloor 2006) and the importance of cultivating a more creative climate in order to support such teamwork. For example, Google's corporate culture is characterized by the provision of the maximum number of opportunities for collaboration in order to stimulate innovative ideas and achieve collaborative creation (Sawyer 2007). Having a creative working climate facilitates the creative capacity of an organization or community (Ismail 2005).

Previous studies of creativity have investigated creative climates in working environments (Amabile and Conti 1999; Ekvall and Tangeberg-Anderson 1986; Isaksen and Ekvall 2010; Zain and Rickards 1996). In particular, researchers have tried to identify factors that affect team creativity by designing surveys and scales to assess the innovative climate within an organization (e.g., Amabile et al. 1996; Ekvall 1996). For example, Amabile et al. (1996) developed instruments that measure the creative atmosphere in an organization by looking into the factors that may hinder or facilitate creativity. They found that an organization's productivity is affected by two factors that hinder creativity (workload pressure and organizational barriers) and six factors that enhance creativity (encouragement from the organization, from leaders, or from team-workers, work autonomy, richness of resources, and the level of challenge at work). Ekvall (1991, 1996) proposed ten factors such as freedom, idea support, trust, risk-taking, and idea time that influence the creative atmosphere within an organization (see Table 2 below for details description of the ten factors). Using these factors, he developed an instrument called the Creative Climate Questionnaire (CCQ) in order to assess the creative climate of organizations. Recently, Hunter et al. (2007) performed a review on creativity climate survey and they identified 14 categories of factors across 42 studies. These factors include positive peer group, positive supervisor relations, resources, challenges, mission clarity, autonomy, positive interpersonal exchange, intellectual stimulation, reward orientation, flexibility and risk taking, product emphasis, top management support, participation and organizational integration. As examples, 'positive peer group' is defined as "perception of a supportive and intellectually stimulating peer group. Relationships are characterized by trust, openness, humor, and good communication." (p. 74); 'challenge' is defined as "perception that jobs and/or tasks are challenging, complex, and interesting—yet at the same time not overly taxing or unduly overwhelming." (p. 74) (see Hunter et al. 2007, for a complete list of description for all factors). Their meta-analysis concluded that while different surveys may be employing different dimensions, they are generally effective predictors of creative performance with medium to large effect sizes. As claimed by Hunter et al. (2007), "all of the dimensions commonly examined in the climate studies produced sizable effects with respect to measures of creativity and innovation" (p. 76). In other words, creative climate exert important influences on creative performances.

As is argued by these studies, an encouraging and supportive environment is more likely to promote knowledge interaction among individuals within and between groups and to inspire innovative ideas that result in more creative products. In order to cultivate a more creative climate, many researchers have also investigated different technological means to support more effective collaboration and knowledge creation. The capacity to make good use of Internet technologies in order to maximize a group's creative potential holds the key to a successful future for collaborative learning and teamwork (Hong et al. 2010; Hong and Sullivan 2009; West and West 2009). Having the pedagogical know-how to design a proper digital environment will play a vital role in promoting group creativity and collaboration, as this would greatly support the generation of innovative ideas, enhance group productivity, facilitate the development of group members' imaginative capacity and thus make knowledge creation more effective.

Knowledge building theory and environment

Paavola et al. (2004) reviewed recent models of knowledge creation and identified the knowledge spiral (Nonaka and Takeuchi 1995), expansive learning (Engestrom 1999) and the KB community (Scardamalia and Bereiter 2006) as three key models that could enhance knowledge creation. Among these three models, the KB approach focuses on transforming conventional school learning environments into more creative ones. Bereiter and Scardamalia's KB theory draws upon and re-contextualizes knowledge creation practices and principles that are often utilized in research, business and scientific communities to transform classrooms (see also Bereiter and Scardamalia 2003; Scardamalia and Bereiter 1999, 2003, 2006). KB is defined as a social process that highlights sustained production and the improvement of ideas which are of value to a community (Scardamalia and Bereiter 2006). As a fundamental approach to educational reform in the field of learning sciences (Sawyer 2006a, b), KB features a principle-based approach to innovation (Hong and Sullivan 2009; Zhang et al. 2011) which emphasizes the nature of learning as a complex system (Barab et al. 1999) and learning processes as emergent and guided by general learning principles. This is in sharp contrast with conventional reform efforts, which highlight ritualistic instructional activities defined by pre-specified procedures, classroom scripts and rules, or componential learning tasks, which lead to the mastery of pre-specified content rather than knowledge creation (Hong and Sullivan 2009).

In order to foster a KB environment, Scardamalia (2002) conceptualized a set of KB principles. Fundamentally, these KB principles are designed to guide the behaviors of, and to enhance relationships between, three essential KB entities: 'idea' (as basic unit for knowledge building), 'agent' (as knowledge worker), and 'community' (as a knowledge sharing and building space), in order to facilitate a more creative learning and working environment. For example, regarding the 'idea' entity, the principle of 'idea diversity' highlights that "[i]dea 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" (p. 79). These principles help build strong relationships among the above mentioned three KB entities for sustained knowledge advancement.

To facilitate a more creative learning environment, a multimedia platform—Knowledge Forum (KF)—was designed to assist with KB activities, providing community members with scaffolding to help them to collectively solve problems of interest and to create new knowledge (Scardamalia 2002; Bereiter and Scardamalia 2003). Within KF, participants can contribute their ideas in the form of notes to "views," which are virtual spaces for collaborative problem-solving. In addition, KF also allows participants to co-author notes, build on, annotate and reference the work of others, add keywords, set problem fields and "rise above" previous notes in order to increase the coherence of the content of the knowledge space. All of these features are designed to foster dynamic idea interaction and in-depth collaboration. All of these online operations can be automatically recorded in a KF database, and can be statistically represented by means of an Analytic Toolkit (Burtis 2002). The KF designs are in line with the overarching commitment to sustained knowledge advancement and the need to enable community members to continually exchange and improve ideas as epistemic agents. As an example, Fig. 1 shows the interface of a KF note with some design features such as using authentic real-life problems to guide the generation of real ideas and improvable ideas, using the text body to elaborate ideas, using keywords to help identify, search for and connect ideas and using customizable scaffolds to frame ideas. By enabling students to engage in sustained 'idea' improvement within KF, they can be guided to become more self-directed epistemic 'agents' and to co-structure their knowledge within the 'community'.

The present study

Scardamalia and Bereiter (1999) argue that an effective learning environment which is operated under KB pedagogy and technology should closely resemble an innovative

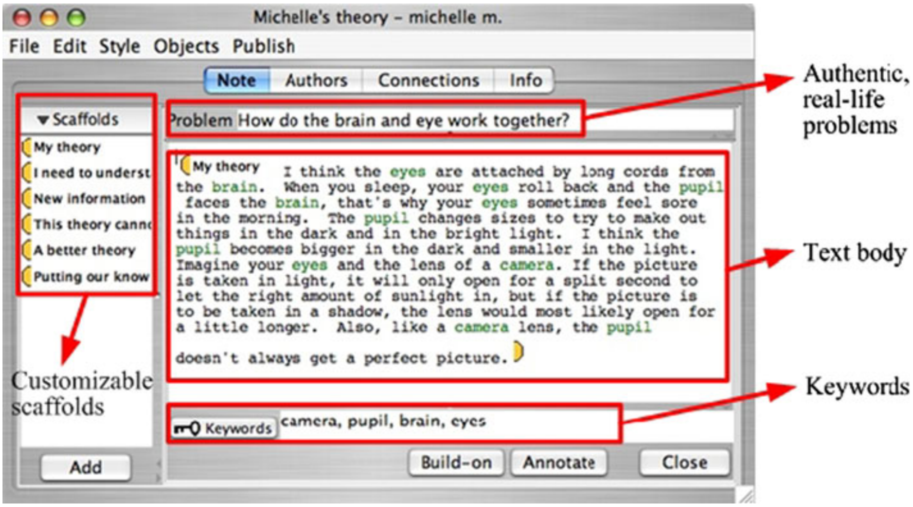

Fig. 1 Some design features of the note interface (source: adapted from KF 4.6 online manual at http://ikit.org/kf/46/help/)

design, research or business working environment. Previous research indicates that the integral use of KB theory and KF technology can help students to learn effectively (Scardamalia 2002; Scardamalia and Bereiter 1994; Zhang et al. 2007). Teacher educators have also pointed out the gap in research pertaining to the development of future teachers' capacity to create and refine ideas and practices, which would directly influence their capacity to bring about knowledge creation in the students they teach (see Chai and Lim 2011; Hong et al. 2011). However, the question of whether a class operated under KB pedagogy and technology would indeed enable a more creative climate that resembles an innovative workplace environment for students' knowledge work remains to be answered. Accordingly, the main research question in the present study is: to what extent can a college course, operated under KB pedagogy and technology, be cultivated to become a more creative learning environment such as an innovative workplace environment? In particular, this study intends to investigate: (1) the extent to which students could actually work collaboratively with knowledge in KF; (2) the extent to which they would perceive the climate of a university course as creative after engaging in KB for a semester; and (3) the extent to which they would rate the quality of this KB course as compared with other non-KB courses.

Method

Context and participants

The present research was conducted in Taiwan on a university course which focused on living technologies. The course was offered by the university's teacher-education program to students who planned to teach living technologies at elementary-school level in the future. The university is ranked as one of the top 10 universities in the nation. Over the past few years, supported by a grant from the nation's Ministry of Education, the university has been deeply dedicated to improving its course quality, with a reform preference toward transforming traditionally more didactic modes of teaching into more constructivist-oriented teaching practices. This reform movement created an opportunity for KB theory and technology to be introduced into this course as an alternative method of teaching and learning. The participants in this course were 30 teacher-education students (20 females). Their ages ranged from 18 to 20. The duration of this course was 18 weeks.

Instructional design

One main instructional goal of this course was to foster a creative class climate by encouraging the students to engage in KB in order to solve real-world technology problems while developing collaborative and creative skills. To this end, KB pedagogy and KF technology were employed in the course design. At the start of the course, a tutorial workshop on the use of KF for KB was given at the beginning of the semester. This was implemented by walking students through some of the basic design features and functions of KF, for example, how to create a note in a "view" (i.e., a virtual problem-solving space in KF) or "build on" an existing note. Figure 2 shows a screenshot of a KF view, in which each square box represents a note generated by a community member or a group of co-authors. In order to elaborate, enrich, exchange or improve ideas, members can provide suggestions or comments by building on existing notes. This action creates a new square box with a link between two square boxes.

As argued by Papert (2000), conventional instructional approaches tend to highlight acquisition of textbook knowledge and to deemphasize student work with ideas, and thus

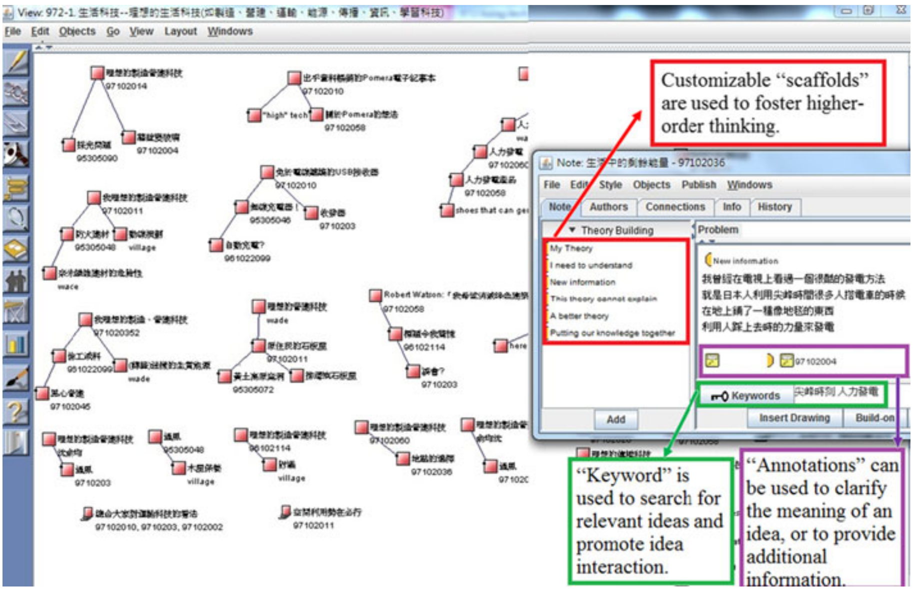

Fig. 2 A screenshot of the Knowledge Forum platform where participants' interaction is reflected. In this figure, each note is represented by a *square box* and each *link* between *two square boxes* represents a build-on activity; and the concept-map like KB view shows the collective effort by community members to build knowledge together. In addition, the design features of customizable 'scaffolds', 'keywords', and 'annotations' are also illustrated with explanations

fostering a learning climate of idea aversion (i.e., dislike of ideas) in class. In contrary, this course engaged students in knowledge building, and to this end, an idea-centered instructional approach (Hong and Sullivan 2009) was adopted in this course. Working innovatively with ideas is essential to knowledge advancement (Scardamalia and Bereiter 2006), and arguably, ideas can be improved in two dimensions: quality and quantity. The quality of ideas is a function of how learners as knowledge workers collaboratively work with ideas, and the quantity of ideas is a function of how ideas are exchanged and diversified in a community. Building on Popper's (1972) conceptualization of evolutionary epistemology, the quality of ideas can be considerably enriched by means of constructive elaboration, and the quantity of ideas can be substantially increased by means of continued diversification. More importantly, ideas need to be improved over time by means of a productive course that enables the transformation of ideas both in quality and quantity through an emerging or self-organizing process enabled by simple rules (e.g., idea elaboration and exchange) in order to gradually help form a complex network of ideas in a community (Prehofer and Bettstetter 2005). Building on this instructional approach, participants were guided to engage in the following four different instructional activities.

Idea generation

In order to encourage students to generate and work with ideas, students were first guided to search for their problem of interest. They were guided to look for as many real-life problems as possible, and then identify a particular problem of interest for later exploration. Examples of real-life technology problems in which students engaged in this course are such as designing a water-saving toilet, an intelligent closet management system, and a human energy generator. Then, students were guided to generate initial ideas or solutions in order to solve their problems of interest.

Idea exchange/diversification

Students were guided to read each other's ideas recorded in notes, to discuss and exchange ideas/solutions for solving their identified problems both in KF and online, using keywords in their notes, in order to diversify their ideas.

Idea elaboration/reflection

Students were guided to further elaborate their ideas, by providing explanations as to how and why their ideas were workable and of value to their class community, and then they reflected on, and evaluate, support or negate certain ideas based on their explanatory coherence (Thagard 1997). This learning and knowledge building process is very similar how scientists (or experts) struggle to continuously improve their scientific theories (or ideas) (Hong and Lin-Siegler 2012).

Idea improvement

Students collaboratively try to improve their ideas by summarizing and synthesizing the explanatorily more powerful ideas and, based on these selected ideas, they tried to design a technology product or solution. Then, at the end of this course, the students shared what they had learned from their KB process with others in the community by giving a presentation about the technology product.

One thing to note is that although students were required to design technology products, no actual products needed to be made; it was the process of working with ideas, rather than producing actual products that was highlighted in the instructional design. As for the four instructional activities, the first two activities mainly focused on fostering students' divergent thinking, while the other two activities focused on convergent thinking (Guilford 1967). Another important thing to note is that the four activities were not necessarily implemented by the students in the order given, but in general students were guided to engage in the first two activities before the mid-term exam and the other two activities after the mid-term. In line with the spirit of knowledge building, the process of student work with ideas was completely emergent, rather than pre-determined. As an example, Fig. 3 shows a student note (translated from Chinese), in which diverse ideas about ideal transportation technology (e.g., autopilot and automatic navigation) were being contributed and shared.

The instructor was familiar with KB theory and pedagogy, and had been using KF in his college teaching for four years. Throughout the semester, the instructor tried to serve as a facilitator in guiding students to work in the four knowledge building activities, in order to allow the students to work collaboratively and creatively with their own problems of interest for sustained idea improvement. There was no pre-assigned grouping in this course; instead, the students planned their own learning by opportunistically deciding with whom to collaborate or with what ideas to interact, based on the nature and type of the problems they were working with at the time (Hong 2011; Zhang et al. 2007).

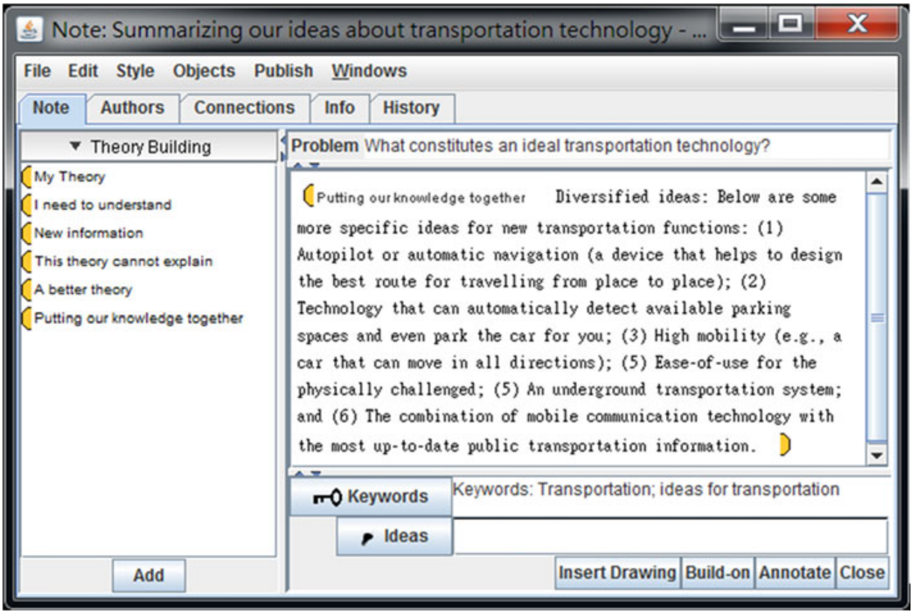

Fig. 3 An example of a student note that shows some diverse ideas contributed

Data sources and analysis

This research employed a mixed approach to collecting and analyzing data. The main data sources included: (1) students' online discourse recorded in a KF database; (2) a modified version of the CCQ by Zeng (2002); and (3) a course evaluation survey.

Students' online discourse in the database

First, in order to assess the learning process, a descriptive analysis was performed on the KF dataset in order to describe the students' overall online discourse and learning activities. Key indicators recorded in the KF database were examined to quantitatively illustrate the overall online performance, for example, the number of notes contributed and built on. In addition, to explore the changing process of KB activities in KF, the semester was divided into two stages, using the mid-term exam as a separation point. T-tests were employed to compare whether there was any difference between the two stages. Next, Gunawardena et al. (1997) Interaction Analysis Model (IAM) was adapted to examine how students collaborate online and the quality of online knowledge work. As Table 1 shows, more advanced phases imply more challenging collaborative activities for knowledge construction. To ensure the quality of coding, two researchers independently coded all of the passages and categorized each of them into a level of the IAM. The inter-rater reliability (Cohen's kappa) was calculated to be 0.81.

Modified version of the Creative Climate Questionnaire (CCQ)

Second, Ekvall's (1991, 1996) CCQ was employed to assess the students' perceived creative climate in this KB class. The original CCQ was developed for use in business organizations. Minor textual modifications were made by Zeng (2002) for its use in school organizations. The CCQ contains ten dimensions (see Table 2 for a description and sample item of each dimension). Laurer (1994) has demonstrated that the ten dimensions of the CCQ are supported theoretically in the creativity literature. In addition, the CCQ has also been tested as a valid and reliable instrument by means of field research, factor-analytic studies and organizational consultancy work (Ekvall 1996). Based on the fact that CCQ has been validated and used in school context (Zeng 2002), its comprehensiveness (ten dimensions), and that the dimensions are generally congruent to the knowledge building classroom environment that we tried to foster, the CCQ is assessed to be relatively the most appropriate instrument for the current study. Each dimension consists of five question items. All of the items adopt a four-point Likert scale. The original scale has an internal consistency reliability level of Cronbach's $\alpha = 0.87$ ($N = 703$), with sub-scales ranging from 0.70 to 0.86. To understand how the participants perceived the climate change, two analyses were made. One is a MANOVA test that was conducted to compare the statistical differences in the mean values between the KB environment (KBE) group (i.e., the group of students in the present study) and a non-KBE group/condition/class. To make the two groups more comparable: (1) first, this non-KBE class ($n = 28$) was selected from the same teacher education program with similar academic background. The students had a very similar achievement-level based on their grades in the previous semester ($F = 1.81$, $p < 0.05$, M = 84.55 for the KBE class, M = 85.92 for the non-KBE class); (2) this is a new course that does not require the students to have pre-requisite knowledge, i.e., pre-existing knowledge is unlikely to determine the outcome of the research since we are not measuring learning achievement in terms of knowledge acquisition; (3) third, major

Table 1 Interaction analysis model adapted from Gunawardena et al. (1997) for the analysis of discourse activity

Phase	Description	Example
0: Not-on-task talking[a]	Utterances that are not directly concerned with the task of improving ideas	Living in the dormitory is inconvenient
		I also want to see the picture
I: Sharing/comparing of information	Statement of initial proposal or idea	Using a plastic mask may be helpful, because moisture in the cloth mask causes mould to grow. In contrast, the plastic mask can be dried immediately after cleaning
		It is really hard to find a parking space downtown. If there was a gadget that could show us whether a car is leaving a nearby parking lot, we could save lots of time spent searching by driving directly to that parking space
II: Discovery and exploration of dissonance or inconsistency among ideas, concepts or statements	Identifying the feasibility, strengths and weaknesses of proposed ideas; stating areas of disagreement	I like the second idea. If a camera can send photos directly to another camera wirelessly, that would be awesome; it is really inconvenient to upload photos online from one camera and then download them to another camera
		Why can such a device prevent dizziness? It is because there is liquid in between the two layers which serves as a buffer, so our vehicle design can reduce the shaking motion while maintaining its balance during movement
III: Negotiation of meaning/co-construction of knowledge	Negotiation or clarification of ideas; identification of areas of improvement; proposal and negotiation of new ideas embodying compromise; co-construction	Although this technology sounds ideal for construction, it would take up a lot of space. In addition, the concept of environmental protection is very good, but its cost is too high
		Making a microchip as a sticker that can paste onto the surface of a cell phone is good, but why not just implant it directly into the cell phone?
IV: Testing and modification of proposed synthesis or co-construction	Testing against an existing cognitive schema, personal experience, formal data or contradictory information in the literature	When testing this idea, one should take into consideration the resistance produced by this [transportation] technology when its tires are made into a shape like a cylinder
		Have you ever considered applying siphon principles in the design of your new bathtub? Doing so can help to evaluate whether extra mechanical power is necessary
V: Agreement statement(s)/ application of newly-constructed meaning	Summarization of agreement(s) and metacognitive statements that illustrate the construction and application of new knowledge	Other special design features [for this transportation technology] include: (1) it can change its capacity according to the number of passengers; (2) when the vehicle breaks down, it can be manually pushed to the roadside; (3) there is an alarm system to wake up a sleepy driver and an auto-pilot system to park the vehicle [on the roadside] if the driver cannot be woken up
		The underground water-heating and circulation device is a system that collects and stores warm water when one takes a bath and then reuses the heat to warm the bathroom floor during winter time

[a] This phase was added by the authors

learning content was concerned with pedagogical knowledge (e.g., how to design and teach living technology to pupils); (4) fourth, students were both engaged in self-directed learning, participated in Knowledge Forum, and were interacting with one another while developing problem-solving capacity; (5) fifth, the same instructor taught both courses; and (6) the main difference between the two conditions was the instructional approaches and it was expected that with knowledge building pedagogy, students would perceive the climate of their learning environment as more creative. So, both groups of students were asked to complete the same CCQ at the end of the course. As it is only sensible to assess the creative climate of a class after a course is finished, no pre-test was conducted.

Course evaluation survey

Third, a course evaluation survey was used to further assess the overall instructional quality of this course operated under KB pedagogy. The survey was designed and validated by the university's Center for Teaching and Learning Development with the main aim of assessing and improving the quality of the university's courses (the University's Office of the Registrar, personal communication). The administration of this survey is mandatory and is routinely performed at the completion of every course. The survey contains 20 response items, such as: "The course was conducive to independent thinking"; "The course was adaptive to students' different aptitude levels"; "The course encouraged

Table 2 Ten dimensions of the CCQ (source: adapted from Ekvall 1996)

Dimension	Description	Sample item
Challenge	The emotional involvement of the members of the organization/community in its operations and goals	Most people here think that their job or school work is meaningful, so they feel excited and stimulated
Freedom	The independent behavior exerted by the members of the organization/community	People here are self-motivated to find information and to solve problems
Idea support	The ways in which new ideas are treated and supported	People here are always willing to share their ideas because they are encouraged to do so and people pay attention to each other's ideas
Trust/openness	The emotional safety in the relationships between members	Everybody trusts each other in this place
Dynamism/liveliness	The eventfulness of life in the organization/community	People here are full of ideas
Playfulness/humor	The spontaneity and ease that is displayed in the organization/community	The atmosphere here is playful
Debates	The occurrence of encounters between viewpoints, ideas and differing experiences and knowledge in the organization/community	Innovative ideas are often generated for discussion in this place
Conflict	The presence of personal and emotional tensions in the organization/community (in contrast to conflicts between ideas)	A lot of people here cannot tolerate each other
Risk-taking	The tolerance of uncertainty in the organization/community	Innovative ideas are adopted and implemented quickly in this place
Idea time	The amount of time people can use to elaborate new ideas in the organization/community	People here are given plenty of time to think about their new ideas

student inquiry and discussion"; "I learned a lot from this course"; and "I would recommend this course to other students." All of the items employed a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Using a randomly selected sample of 175 students from 10 different courses offered by the university's teacher education program, Cronbach's alpha for reliability was calculated to be 0.95. For the purpose of analysis, an independent samples *t* test was computed to ascertain whether there was any difference between the mean evaluation rating of this KB course and that of all the non-KB courses offered by the university.

Results

Online learning behaviors

Figure 4 shows the overall pattern of note-linking at the end of the semester to illustrate the highly collaborative nature of this course in terms of its quantity. In order to further examine how students learn and work with knowledge in the community, a descriptive analysis was performed. Table 3 shows data regarding basic KB activities which was used to show the intensity of collaborative learning activities over the semester, with two stages—each lasting for nine weeks—divided using the mid-term exam as a separation point. Overall, the paired-sample *t* tests indicate that there were no significant differences

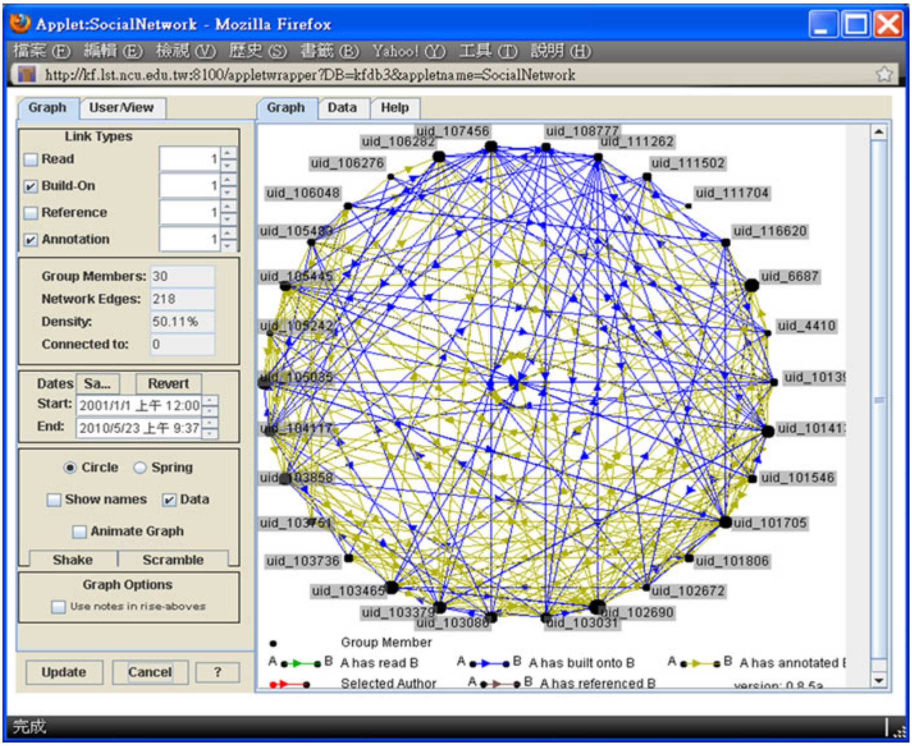

Fig. 4 Illustration of online connectivity patterns (including build on and annotation) for the whole class community at the end of the course

Table 3 Basic KB activities

	Stage 1		Stage 2		*t* value
	M	SD	M	SD	
# of notes contributed	7.63	3.44	7.70	4.14	−0.07
# of notes built on	4.39	2.29	5.43	3.54	−1.22
# of annotations	4.90	5.01	4.50	8.80	0.35
# of scaffold supports	4.30	4.25	3.67	4.01	1.23
# of problems worked on	0.73	1.36	1.17	2.51	−1.54
# of notes read	111.83	58.40	133.83	94.31	−1.45
% of notes linked	0.49	0.23	0.52	0.30	−0.45
% of notes with keywords	0.46	0.29	0.42	0.35	1.00

The data presented above were based on number of notes (or annotations or problems) posted per student

between the two stages in terms of, for instance, the number of notes contributed, built on, read and linked, the number of annotations and the number of scaffold support structures. In terms of the quantity of online activities, the above analysis suggests that the time and effort spent on learning and using KF for discussion purposes was equally distributed between the two stages (i.e., students were able to work together online in a consistent and sustained manner). This quantitative comparison analysis, however, only shows the amount of online activity in a general sense. It does not specifically reveal the quality of the online collaboration. To provide more in-depth information, the quality of student interaction and collaboration was further analyzed.

Table 4 further provides an overview of the distribution of students' online discourse between the two KB stages, according to the phases of knowledge construction adapted from Gunawardena et al.'s (1997) IAM. It was found that there was a statistically significant drop in the mean values from Stage 1 to Stage 2 in terms of not-on-task talking (Phase 0) and that there was no significant difference between the two stages in terms of Phase I (sharing/comparing of information). On the other hand, there were statistically significant increases in the mean values from Stage 1 to Stage 2 in Phases II–V. As mentioned above, more advanced phases imply more meta-cognitively and collaboratively demanding activities when they feature as part of the knowledge construction process. The findings, therefore, suggest that the students gained KB momentum over time when working in KF. It is worth noting that the mean value in Phase IV is relatively lower than the equivalent in the other three phases (Phases II, III and V). This is perhaps because the students on this course were required to produce a technology prototype on paper, rather than to design an actual technology object that would require practical testing, and so the number of testing activities was low. Nevertheless, the findings still suggest that there was an overall high intensity of collaborative knowledge construction activities as the course unfolded. There is some evidence of a relationship between the intensity of discussions (based on the number of coded ideas) and the quality of contributions to the collaborative construction of knowledge. In short, from a process perspective, the findings show that the students were able to interact in a collaborative manner for the purpose of continuous knowledge advancement.

Creative climate of the KB environment

As an outcome measure, the present study assessed the students' perceptions of the creative climate of the KB environment at the end of the semester. A MANOVA test was conducted

Table 4 Knowledge co-construction activities in KF between two KB stages

Phase	KB Stage 1		KB Stage 2		t value
	M	SD	M	SD	
0: Not-on-task talking	1.6	2.37	0.77	1.92	2.98**
I: Sharing/comparing of information	3.63	2.94	2.8	3.03	0.99
II: Discovery and exploration of dissonance or inconsistency among ideas, concepts or statements	1.2	1.3	7.83	3.75	−9.88***
III: Negotiation of meaning/co-construction of knowledge	1.47	1.7	7.24	4.48	−8.89***
IV: Testing and modification of proposed synthesis or co-construction	0.07	0.25	1.53	1.16	−6.73***
V: Agreement statement(s)/applications of newly-constructed meaning	0	0	5.2	4.08	−6.97***

The data presented above were based on number of notes (or annotations or problems) posted per student

** $p < 0.01$;*** $p < 0.001$

that compared the statistical differences between the mean ratings of the CCQ survey in the KBE group/class and in the non-KBE (comparison) group/class. The results indicated an overall significant difference between the two groups (Wilk's $\lambda = 0.19$, $F = 20.40$, $p = 0.000$, $\eta^2 = 0.81$), in that students who were engaged in KB tended to give more favorable ratings on the CCQ. Specifically, it was found that significant differences occurred on all 10 assessed dimensions of the creative climate. Table 5 shows further detailed results regarding the mean value, standard deviation, F value and η^2 of the two groups. The findings suggest that idea-centered KB, as a pedagogical approach, provides a favorable, creative climate for students than non-KB pedagogical approaches.

An essential instructional goal of this study is to foster an innovative environment that is characterized by knowledge creation. The results outlined above confirm that students engaged in a KB environment are more likely to perceive it as a creative environment. As such, a further question worth asking may be: To what extent is the current KB environment

Table 5 Perceived creative climate between two different learning environments: A MANOVA test

	KB environment ($N = 30$)		Non-KB environment ($N = 28$)		F value	η^2
	M	SD	M	SD		
Challenge	3.04	0.39	2.49	0.40	28.81***	0.34
Freedom	2.99	0.43	2.61	0.40	12.40***	0.18
Idea support	3.44	0.39	2.55	0.38	80.13***	0.59
Trust/openness	3.29	0.35	2.54	0.44	54.11***	0.49
Dynamism/liveliness	3.39	0.34	2.38	0.32	141.41***	0.72
Playfulness/humor	3.44	0.39	2.24	0.35	159.03***	0.74
Debates	3.4	0.37	2.61	0.42	60.99***	0.52
Conflict	1.34	0.35	1.79	0.52	15.58***	0.22
Risk-taking	2.86	0.45	2.36	0.32	25.05***	0.31
Idea time	3.1	0.38	2.38	0.37	54.48***	0.49

*** $p < 0.001$

similar to or different from other more commonly observed creative working environments, such as an innovative business working environment? To answer this question will for sure require a different study specifically focusing on comparing a KB environment and a working environment.

Course quality evaluation

Further, the university's course evaluation survey, which used a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was employed at the end of the course. This additional investigation was conducted to compare the overall perceived quality of this course, designed based on KB theory and technology, with other non-KB courses offered: (1) by the university's teacher education program in particular; and (2) by the university as a whole. As a general description, a total of 51 courses were offered by the teacher education program in the university in the given semester, and the mean course evaluation rating for all of these courses was 4.09 (SD = 0.48)—the mean value '4.09' was calculated by averaging all ratings obtained from the 20 question items. In contrast, there were a total of 1,797 courses offered by the whole university in the given semester, and the mean course evaluation rating of all of these courses was 4.14 (SD = 0.36). As regards the present course, the mean course evaluation rating was 4.46 (SD = 0.19). The mean evaluation rating of the present course is higher than that of the courses offered by either the teacher education program or the university as a whole. The findings indicate that the participating students' perception of learning in the present course was generally positive.

Discussion and conclusion

The scholarly literature on school reform and innovation has argued for the importance of transforming schools into knowledge-creating organizations (Bereiter and Scardamalia 2003; Hargreaves 1999; Sawyer 2006a, b, 2007; Scardamalia and Bereiter 1999). The empirical findings of this study further substantiate that it is possible to cultivate, within a classroom setting, a creative climate (see also Zhang et al. 2011). In summary, from a process perspective, it was found that the participating students were able to work more collaboratively and productively with ideas when addressing their identified problems of interest within a KB environment. This was evidenced by the descriptive analyses of the participants' online discourse activities, as the participants were able to consistently create notes, and build on the work of others, add keywords, etc., in order to collectively enrich and deepen their ideas and address the technology-related topics at hand. Furthermore, an assessment using the IAM showed that students become more collaborative over time when constructing collective knowledge. From an outcome perspective, the results of the CCQ survey suggest that after working in a KB environment for a semester, the participants tended to perceive the climate of this environment they were working in as relatively more creative (M = 2.97, SD = 0.82; as compared with the mean value of 2.5 out of a four-point Likert scale). In addition, the course evaluation results indicated that the participants' perceptions of the quality of this course also tended to be more positive. This is in sharp contrast with the lower course evaluation ratings reported for all the other non-KB courses provided by the university. Together, the findings indicate a desirable change in the present course implemented under the support of the idea-centered KB instruction.

In the fields of learning sciences and organizational science, there has been an intensive focus on ways to foster knowledge creation at a group level rather than at an individual level (von Krogh et al. 2000; Sawyer 2007). As such, organizations of all kinds (businesses and schools) are striving to find ways to design effective learning and working environments in support of group work and innovation (Hong et al. 2010; Gloor 2006; Stahl 2006). This is especially important as the world is changing so rapidly that many real-life issues have become too complex (e.g., global warming) to be solved by an individual genius. Instead, in order to solve these issues effectively, society must rely on more effective collaborative knowledge creation (Sawyer 2007). In a knowledge society, the ability to develop new knowledge has become more and more important as a necessary skill for daily work. This is in contrast with the traditional notion of creativity, which has often been regarded as a trait belonging to an exceptional genius (i.e., only the selected few who are able to carry out innovative work). Accordingly, in order to better prepare students to enter a knowledge-based society that values collaborative creativity, it is critical to help foster within conventional school environments a more creative climate that values collaborative knowledge construction. It is also equally important for educators to help to transform the conventionally-held belief in education that it is best to learn first (e.g., through K-12 schooling) and to innovate later (e.g., during graduate study or after going to work), so that the cultivation of KB environments at all levels of school organizations will be possible. As Chai and Lim (2011) argued, for teacher education to be effective in the next century, it is important to encourage teachers to work on ideas and cognitive artifacts. Given that teachers are the key to transforming the classroom, they should have first-hand experience of improving ideas in a collaborative setting. This study provides a case example of how teacher educators may cultivate the knowledge co-construction capacity of future teachers. It is argued that teachers who are equipped with experience of collaborative KB are more able to support the transformation of a school into a knowledge creation organization.

The present study provided an initial look at teacher education students' perceptions of the creative climate in a KBE enabled by KF technology. Admittedly, there are limitations of this study. One concerns the generalizability of results derived from a single class setting. Although some scholars (e.g., Cobb 2001; Steffe and Thompson 2000) argue that studies grounded in classroom analyses can be generalizable, as insights gained from such analyses can inform the interpretation of instruction in a similar context, future research should be conducted using a bigger sample size. Moreover, this study investigated the collaborative learning process and creative atmosphere of a course. It may be fruitful to further explore the question of whether student engagement in KB would also affect students' knowledge-creating capacity and problem-solving ability, while taking into account of other related variables (such as students' prior knowledge, learning goals, self-efficacy expectations, interest, etc.), in order to assess in detail who may benefit more from such a learning environment. Moreover, the present study used the CCQ to measure the creative climate. The creativity literature notes similar instruments that also measure the creativity of an organizational atmosphere (for example, see Amabile et al. 1996; Watkins and Marsick 1999). Future research may use other types of creativity instruments to triangulate the findings of the present study. Future studies may also look into the correlations between the perceived creative climate and other more affective or domain-specific measures such as students' interest in the topic of the course, students' level of satisfaction with the course and platform, students' perceived enjoyment, and students' perception of difficulty, to better understand how to foster a more creative learning environment. Admittedly, as no highly controlled comparison groups were employed in this study, it remains unclear whether or not KB instruction and technology alone are fully accountable for all of the changes observed in the current case study. To make up for this deficiency, a comparison between a KB and non-KB environment was intentionally conducted as an analysis in this study. Although the comparison was made to be as comparable as possible, students' prior knowledge may still play a role in influencing how they may participate and perform in the respective environment. In the future, better-controlled comparative research should be employed in order to fully answer the research questions. Relatedly, it may also be interesting to compare how students' actual online performance (e.g., contribution and interactions) with the self-assessment of their interactions, and whether they are aware of their personal knowledge growth and improvement of KB capacity.

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