Education Tech Research Dev
https://doi.org/10.1007/s11423-024-10389-3

DEVELOPMENT ARTICLE

The use of distance-shortening strategies to enhance opportunistic collaboration in knowledge-building environments

Yujie Chen[1] · **Yibing Zhang**[2]

Accepted: 27 May 2024

Abstract
Carrying out opportunistic collaboration, a method of flexible collaboration centering around ideas and free collaboration structures, is important in knowledge creation organizations, especially for knowledge-building community formation. However, fixed-group collaboration is still widely employed in educational practice, hindering the development of students' knowledge creation activities. In this design-based study, we created and applied distance-shortening strategies, which are strategies for shortening students' physical distance and idea distance, to support their opportunistic collaboration. The participants were 24 master's degree students who took a required one-semester course titled Learning Sciences in Knowledge-Building Environments that included online and offline activities. Data included (1) records of students' online activities; (2) video clips of students' offline activities; and (3) the content of students' online notes. Social network analysis, video analysis and content analysis were applied. The findings revealed that with distance-shortening strategies for constructing community knowledge and collective responsibility, the students were able to overcome the barriers of a fixed group and engage in opportunistic collaboration. Implications for principle-based and design-oriented knowledge-building activities and approaches to fostering knowledge creation are discussed.

Keywords Opportunistic collaboration · Knowledge building · Distance shortening · Design-based research

Introduction

With the advent of the knowledge society, knowledge workers today need to adapt to the culture of knowledge creation (Karlgren et al., 2020). As noted by Hong (2011), scientific knowledge is socially constructed (see also Popper, 1972; Bereiter, 2005), and knowledge creation is regarded as the result of social dynamics (Rutten, 2017; Sawyer, 2007) rather

✉ Yujie Chen
yujiechen29800@outlook.com

[1] School of Teacher Education, Huzhou University, Huzhou, China

[2] School of Education Science, Nanjing Normal University, Nanjing, China

Published online: 10 June 2024

than individual creativity. Thus, the importance of collaboration has been highlighted in the literature. In particular, different research has suggested that creative work can be better supported through collaboration, which features flexible, adaptive and distributed social structures, than through collaboration with rigid and fixed structures (Chatzkel, 2003; Engeström, 2008; Gorelick et al., 2004; Handy, 1989; Perritano & Moher, 2019; Sawyer, 2003). Kraut et al. (1990) concluded that the majority of collaborations in R&D organizations are loosely structured and nonhierarchical by nature and thus support knowledge production work and provide a critical arena in which collaborators can start joint work and generate fresh ideas.

This kind of collaboration is named opportunistic collaboration. It is a cross-disciplinary concept that is mentioned in different research areas, such as knowledge management and computer-supported cooperative work (CSCW). Defining opportunistic collaboration involves understanding the meaning of opportunism and understanding what it is meant to be a collaborating process. In CSCW, opportunistic collaboration is often regarded as ad hoc cooperation (Khalid et al., 2021), which is characterized by emergent and unplanned collaboration. According to research in organizational learning, it is argued that creating more opportunistic ways of collaboration and flattening organizational structures are key conditions for successful organizations (Tang et al., 2017), which indicates that opportunistic collaboration happens in unstructured work environments, supporting and encouraging people to explore, capture and realize their collaborative potential (Naeve, 2010). In the educational context, Hong (2011) also clarified that opportunistic collaboration focuses much more on collaborators' diverse ideas rather than forming specific fixed groups. To this end, opportunistic collaboration can be summarized under three key elements: (1) emergent process and shared interests, (2) loosely structured environment, and (3) idea-centered collaboration. We defined opportunistic collaboration as an unplanned, nongroup-based, and self-organizing way for people to creatively and collectively collaborate in a team or community, where groups are highly reconfigurable and are not predefined from the beginning. Groups form, break up, and recombine as part of an emerging process to regulate and coordinate collaborators' own work. Opportunistic collaboration is generally found in research, science, and business communities where knowledge creation is frequent and people can interact with each other spontaneously. (Gloor, 2006; Naeve, 2010). In poster sessions and workshops, for instance, people voluntarily collaborate based on emergent goals. Additionally, Wikipedia was originally developed by and continues to exist through people collaborating on diversified ideas without forming a specific group. The well-known Homebrew Computer Club in Silicon Valley, which has achieved significant innovation success in technology, began when a group of people who were interested in computers began gathering regularly, exchanging ideas, and collaborating freely (Defillippi et al., 2006). As Chatzkel (2003) asserted, "people need to feel free to move about in their organization, to group and regroup in different organizations as needed".

In this context, there is a growing demand for schools to support students engaging in opportunistic collaboration to meet the needs of the future (Hong, 2011) since traditional fixed-group collaboration is decreasingly able to respond properly to many of the challenges that face students today when the demand for knowledge innovation is ever-increasing. In fixed groups, students tend to form the fixed groups with someone they are familiar with and they complete their collaborative tasks while acting in accordance with their designated roles, such as source finder and summarizer (De Wever et al., 2008; Zhang et al., 2022), which hinder students' full potential and limit their possibilities for knowledge creation. A classical theory – the strength of weak ties proposed by Granovetter (1977) – also proved that the stronger relations (ties) are

among people, the more congruent their ideas are. Weak ties can create more paths for people to obtain more different ideas and information and have a significant impact on idea diffusion and sharing. In other words, students who collaborate with each other in fixed groups have strong ties among them that may lead them to generate similar ideas influencing the generation of innovation. Weak ties are needed in innovation-oriented collaboration. Moreover, from the perspective of our changing society, we have long understood that we are living in a global context that is extremely complex and uncertain, where colleagues, clients, partners and providers are constantly changing—a world where you can never be certain with whom you will be dealing from one day to the next (Hargreaves, 1994). Therefore, students are supposed to become accustomed to collaboration changes beforehand. That is, fixed-group collaboration needs to be updated.

Educational researchers have realized that one way to help students adapt to opportunistic collaboration and become future knowledge workers may be to engage them in actual knowledge-building practices based on knowledge-building (KB) theory, defined as a social process with a focus on "the production and continual improvement of ideas that are valuable to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions"(Scardamalia & Bereiter, 2003). Knowledge-building pedagogy aims to create a holistic learning environment that emphasizes learner agency, idea-refinement and promising collaborative discourse (Wu & Wang, 2023). In a knowledge-building community, students' idea development is often supported by a software program named Knowledge Forum (KF). In addition, the knowledge-building process is principle-based (see Appendix 1 for a brief introduction of 12 principles), and it emphasizes educating students on an idea-centered view of collaboration and working with emergent ideas and goals, which distinguishes it from procedure- and task-oriented pedagogical approaches and is just fit for the idea of opportunistic collaboration. For example, the principle of "community knowledge, collective responsibility" states that "Contributions to shared, top-level goals of the organization are prized and rewarded as much as individual achievements. Team members produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community."

However, in some cases, students and teachers are not used to opportunistic collaboration. Students are often assigned to a group and asked to finish a whole task by each doing part of it (Chang & Benson, 2020; Yu, 2017). The Jigsaw method, first used by Aronson et al. (1978), is a pedagogical method that involves dividing a topic into smaller segments and assigning each segment to a group of students. The students then become experts on their segment and teach it to the rest of the class. Obviously, such collaborative learning is group-based and contains well-defined tasks, which is effective but also makes students accustomed to waiting for assigned tasks and being arranged and controlled in groups (Husain et al., 2013). In some other cases, when knowledge-building pedagogy is employed in class, students who do not have experience with knowledge building tend to neglect others' ideas and read content only from their own groups on KF or discuss material within a specific fixed group according to their responsibilities (Zhang et al., 2009). Even though some teachers are aware of the importance of opportunistic collaboration, they lack ideas about how to encourage students to engage in it (Chen, 2022). Therefore, in this work, we designed strategies to help students engage in opportunistic collaboration, thus improving their collaboration ability and allowing them to adapt to the future of innovation culture.

Literature review

Opportunistic collaboration in knowledge-building environments

Opportunistic collaboration has received much attention among a variety of researchers in the past despite its history of being undervalued and overlooked in terms of its potential for innovation. Recent research in education indicates that opportunistic collaboration is a trend that is reflected in the shift in focus from traditional teaching to innovative learning within a social context (Naeve, 2010; Zhang et al., 2022). Likewise, knowledge building is the theory and pedagogy of reforming education to build a knowledge-creating culture of working with ideas and working beyond groups as well as encouraging students to become knowledge workers (Jiang et al., 2022; Lin et al., 2019). In other words, opportunistic collaboration is suitable for knowledge-building pedagogy.

Over the past decade, research on opportunistic collaboration in knowledge-building communities has been virtually all result-oriented, focusing on and verifying the advantages and final results of opportunistic collaboration, while research on the process of helping students form opportunistic collaboration is rare. For instance, studies have shown that, compared to fixed-group collaboration, opportunistic collaboration in a knowledge-building community can lead to a higher level of collective responsibility; more pervasive, flexible, and distributed collaboration; and more dynamic diffusion of information and knowledge advances (Siqin et al., 2013, 2015; Zhang et al., 2009). Zhang's team used a qualitative research method to investigate how students initiate and develop opportunistic collaboration over time in a fifth grade science knowledge-building community (Tian & Zhang, 2017). They also proposed that opportunistic collaboration may be supported using coconstructed framing of inquiry directions that guide student participation and an effective tool was created to help students see knowledge flows (Zhang et al., 2018, 2022), which is productive and necessary for opportunistic collaboration. However, relatively less attention has been given to teaching strategies for promoting and helping students engage in opportunistic collaboration. How does opportunistic collaboration happen? How students who are unfamiliar with knowledge building start engaging in opportunistic collaboration is an avenue for future research.

Strategies for improving opportunistic collaboration

Some studies have shown why many chances for engaging in opportunistic collaboration are lost. As summarized by Moreno et al. (2003), in most cases, people were unaware of their peers' ideas and unaware of the potential relations among different ideas. Thus, in a collaborative learning context, helping students become aware of opportunities for opportunistic collaboration is key. This awareness can be increased in a variety of ways. One study designed a framework for awareness support in groupware systems by collecting information on users' past events, such as the evolution of shared data and users' actions (Kirsch-Pinheiro et al., 2003), which implied the importance of collaborators' past performance in forming opportunistic collaboration. Another study concluded that awareness was closely related to collaborators' motivation and expectations. Collaboration would happen if a collaborator had a clear belief that participation could solve their problems and that they could benefit from it (Hoffman & Herrmann, 2001). In addition, an early study demonstrated that to support distributed cooperative work, collaborators need to be

given direct and easy access to others' ideas; for instance, they should be provided with space and time to encounter others on an unplanned basis (Root, 1988). All these studies were from the field of computer-supported cooperative work (CSCW), and we conclude that opportunistic collaboration can be encouraged by increasing students' awareness of sharing, reinforcing their motivation to collaborate and providing more opportunities and appropriate spaces for informal interactions.

In addition to the CSCW area, educational researchers have been researching this topic. They have claimed that it is common for students to collaborate with their friends or those they are familiar with (Zhang et al., 2009). Thus, Zhang's team concluded that common interests and social boundaries in a class are essential for students to engage in opportunistic collaboration, which explains why they conducted class meetings as a major teaching strategy (Tian & Zhang, 2017). Some of the educational researchers, for instance, tried to use the knowledge building circle, which refers to the seating configuration of students as they sit close in a circle, engaging in flexible knowledge building discourse (Anderson et al., 2017). Using a social network analysis tool and semantic analysis tool, Hong et al. (2010) noted that it is essential to extend students' social metacognitive ability to improve opportunistic collaboration, that is, to help students know who is working on which ideas to advance what cutting-edge knowledge. In addition, Cacciamani (2010) also proposed several strategies to support self-organizing inquiry and opportunistic collaboration for elaborating course content to improve students' understanding and develop their metacognition with a greater focus on idea development.

In conclusion, researchers have proposed many ideas from different perspectives for engaging students in opportunistic collaboration. However, their strategies are scattered in different research areas, as shown in Table 1 below. Some of the strategies focused on enhancing the object condition, that is, environmental settings, while some of the strategies focused on enhancing people's cognitive condition, for example, awareness, motivation, metacognition, etc. How educators can systematically design and implement proper strategies remains unclear.

Distance-shortening strategies

To determine systematically reasonable strategies, we tried to summarize on the basis of the strategies for improving opportunistic collaboration and found some common ground. First, the aforementioned strategies that focused on enhancing environmental settings, such as implementing KB circles and providing spaces for people to encounter others, actually bring different collaborators closer physically and make them active with movement and social interaction. In other words, enhancing environmental settings to reinforce social interaction is a way to break the boundaries of space and social relations so that students can move around and have open collaboration and make different ideas easy and direct to obtain (Anderson et al., 2017). Although not all physical movements or social interactions lead to collaboration, all collaboration is a product of social interaction (Healion et al., 2017). In addition, the literature from multi-model learning analytics has explored and examined the roles of physical movements in collaborative activities. Research has revealed that groups that spend a higher proportion of their time in movements perform tasks significantly better (Reilly et al., 2018). The results of an action study by Braniff (2011) showed that when students were out of their seat, moving around the classroom and working at alternate locations, they produced higher-quality work on collaboration.

Table 1 Strategies summarized for improving opportunistic collaboration

Research area	Specific strategies	Focus
CSCW	Increase awareness of collaborating with different people	Cognitive conditions
	Provide with space and time to encounter others on an unplanned basis	Environmental settings
KB in education	Find more common interests and strengthen social boundaries among students	Cognitive conditions
	Foster students' social metacognitive abilities	Cognitive conditions
	Knowledge building circles	Environmental settings
	Improve students' understanding and develop their metacognition with a greater focus on idea development	Cognitive conditions

Second, in the knowledge building community, different ideas may have the potential to be together, interact with each other and rise above as well as be updated into a more brilliant new idea (Goldenberg et al., 2013). The strategies focused on enhancing cognitive conditions, such as developing collaborators' social metacognitive abilities to know who is working on which idea, as mentioned in Table 1, essentially make collaborators understand idea flows and guide collaborators' participation (Zhang et al., 2022). In this way, the exposure to diverse ideas would be enhanced, which may favor the formation of groups of open-minded people as well as reduce "the echo chamber effect" (Cinelli et al., 2021). In this context, ideas may gradually become closely connected; that is, the idea distance, namely the connection status of ideas, becomes tight and close.

Hence, we can conclude that the strategies focused on either changing environmental settings or cognition conditions are interventions toward shortening collaborators' physical and idea distance, namely, distance-shortening strategies in essence. The construal level theory (CLT), however, has already proven that people perceive and think about events based on their temporal distance, spatial distance, social distance and hypotheticality. The shorter the distance is, the more concrete the perception of events is (Trope & Liberman, 2010). At this point, shortening space and social distance is reasonable and well-grounded for creating a sound knowledge building environment to generate diverse and concrete ideas, as well as having thorough discussions.

We attempted to change collaboration configurations to improve collaborative learning and reinforce students' knowledge creation and innovation in the knowledge-building community. Thus, we aimed to answer the following questions:

(1) Do distance-shortening strategies help students become better opportunistic collaborators?
(2) How does the pedagogical intervention of shortening students' physical distance and shortening their idea distance help them collaborate with each other and improve their ideas?

Methods

Participants and context

The setting for the study was a university in Nanjing, China. Twenty-four year-one master's degree students majoring in educational technology with an average age of twenty-three, an experienced professor who had been immersed in knowledge building for several years, and one researcher participated in this study. All students were new to the concept of knowledge building. They were accustomed to traditional lecture-style teaching and fixed-group collaboration and had never experienced innovation teaching aimed at knowledge creation. In addition, all students got along well, and they were acquainted with each other; it was easy for them to communicate with each other.

The course was on learning sciences and used the Cambridge Handbook of Learning Science as a reference. The aim of the curriculum was to enable the students to understand the key theories and methods of learning sciences. The whole teaching practicum lasted for one semester, a total of 3 months, with 36 in-class hours and 12 in-person activities and online activities in a computer-supported collaborative environment, i.e., KF, which served

as a shared space for students to input their ideas and notes as well as to continue and deepen their inquiry into collective work.

Research design

Design of distance-shortening strategies

Supported by previous research and the aforementioned literature, we generally determined the direction of teaching strategies to engage students in opportunistic collaboration, which is to intervene in environmental settings and students' awareness of different ideas. From a broader perspective, many classical theories or models also support the framework of this intervention. Lewin's (1951) field theory included the formula B = f(P, E), indicating that the behavior of people in groups is determined by the interaction of each person with their environment. In other words, engaging students in opportunistic collaboration is consistent with Lewin's belief that the environment is a vital objective condition. The Community of Inquiry (COI) model is designed to create a collaborative learning environment where students can engage in inquiry-based discussions. The COI model is based on three elements: cognitive presence, social presence and teaching presence (Garrison et al., 1999), corresponding to students' awareness of idea relations, their social distance and teachers' intervention in this research, which provide insights into the strategy design for opportunistic collaboration. In addition, Stahl's (2000) model of collaborative knowledge building also provides ideas for opportunistic collaboration. Stahl's model is a social process model of learning that includes several distinct phases that make up a cycle of personal, small group and community knowledge building (Henderikx et al., 2023). Emergent interactional resources can mediate between different levels of knowledge building (Stahl, 2013). Opportunistic collaboration, as a way to form emergent and flexible small groups, may be a mediator connecting the personal level and community level of knowledge building.

Overall, confirmed and supported by different strategies, models and theories, it is clear that opportunistic collaboration is important for different levels of knowledge building and can be improved by environmental and cognitive methods. Therefore, we carefully designed our study around environmental settings and further improved students' cognitive conditions, helping them understand and accept opportunistic collaboration. We named the attempts that bring collaborators closer physically and psychologically distance-shortening strategies. The distance-shortening strategies are (1) shortening students' physical distance, making them be together rather than separated into specific small groups, which may break the limitation of fixed and unchanged groups and collaborate beyond groups in an idea-centered way; and (2) further shortening their idea distance, enhancing the connections of different ideas, with the aim of changing the context of idea isolation and improving interaction.

Design-based research methodology

This research sought to determine effective pedagogical interventions to help students engage in opportunistic collaboration and adapt to a culture of innovative collaboration. It was a complex educational problem in a real knowledge-building setting, where multiple elements, for instance, students' motivation, awareness, environmental settings, etc., were

involved. Therefore, traditional experimental designs that occur in the laboratory and test the causal impact were not suitable for the present research.

We employed design-based research (DBR) (Mckenney & Reeves, 2018) in the present study. As a developing research methodology in the field of learning sciences, DBR addresses complexity by using carefully designed interventions and iteratively tests and redesigns them to solve complex educational problems over time in naturalistic contexts (Hong et al., 2019). It also allows for the investigation of multiple interrelated and interacting variables, and offers insights into why and how a particular intervention works, thereby providing systems-level understanding (Barab, 2014). As the present study intends to design and adapt the use of distance-shortening strategies as a pedagogical intervention to address a common and important issue concerning the effective utilization of opportunistic collaboration, DBR appears to be a reasonable and relevant method for this research.

Using DBR, the research followed a cyclical process:

- *Analysis and investigation* of the research problem and the needs of the present learning context through a literature review and observations of previous research.
- *Design and implementation* through the idea of distance-shortening strategies, which was part of the iterative refinement process.
- *Evaluation and reflection* of implementation efficacy based on our analysis and observation of student data.

This paper provides an overview of the DBR process, from the preliminary exploration of opportunistic collaboration through two iteration cycles, and concludes with the results and a reflection on the overall research process (see Fig. 1). The shared goal of the two iteration cycles was to help students eliminate fixed-group boundaries and understand each other's ideas across the whole community. All strategies and activities were guided by the 12 knowledge-building principles, especially emphasizing the principle of "community knowledge, collective responsibility" for students' contributions to improve their collective knowledge in class.

Pedagogical approaches

For the overall pedagogical design (see Fig. 2), each student was guided by the following knowledge-building process. (1) Idea generation: The teacher tried to help all students propose authentic problems and ideas related to the learning sciences by citing a relevant situation and introducing students with some fascinating teaching cases that are related to the theory and practice of learning sciences. For instance, the teacher presented how an experienced primary school teacher designed a writing course using the theory of project-based learning. (2) Idea diversification: The teacher and students had several face-to-face discussions about their ideas and problems to produce more ideas. Afterward, numerous group topics emerged from the students' problems and ideas. We encouraged the students to discuss their ideas with each other as much as they could, add their notes to KF, and build on others' notes. (3) Idea elaboration: The students continued their exploration based on different topics. During their exploration, the researcher and teacher intervened with distance-shortening strategies in two design cycles to engage the students in opportunistic collaboration and transform their group knowledge into community knowledge. To

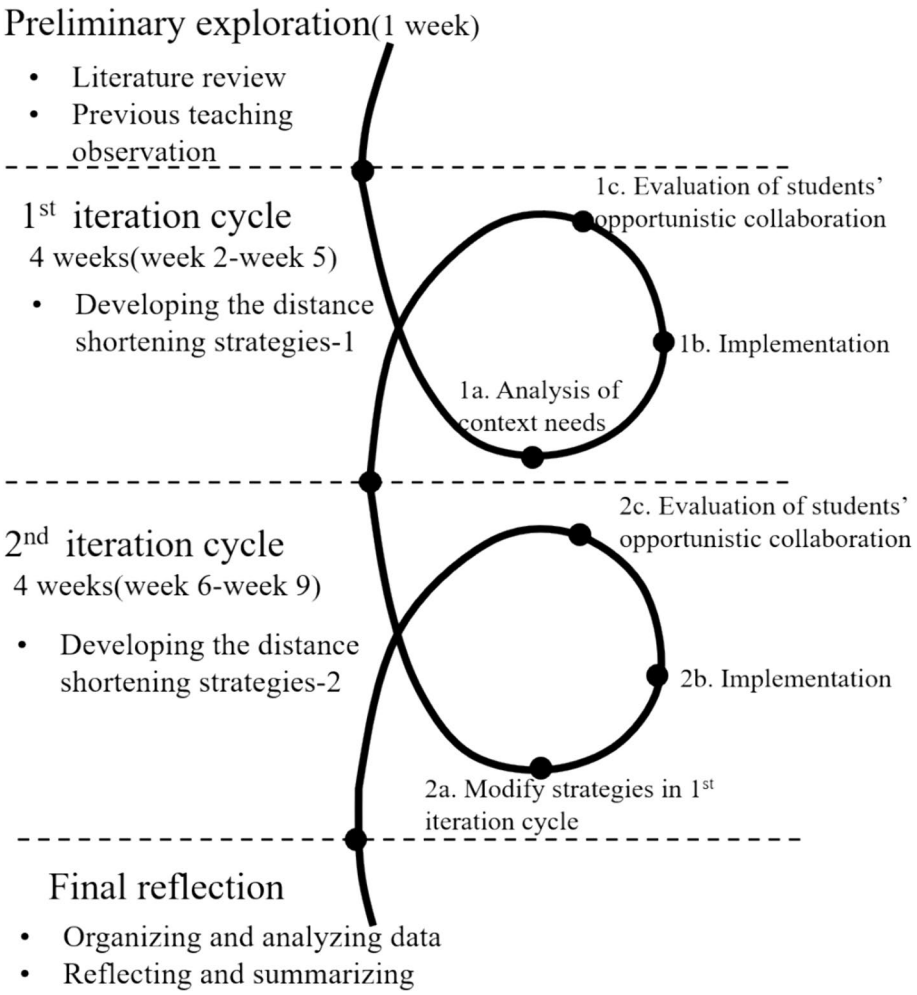


Fig. 1 Design-based research with two iterative design cycles

elaborate students' ideas generated from authentic and practical educational issues, every topic that the students raised was explored through a three-step process:

- *Establishment of the theoretical foundation*: The students learn about theories of the learning sciences that are related to their problems and ideas under the guidance of the teacher;
- *Design and application*: The students are encouraged to apply the theoretical foundation that they have learned in the first step and try to solve the problems and improve their ideas that they have proposed. For instance, they design a course or a project using their established theoretical foundation like educational experts, or they make plans for an educational product based on the theory they have just learned;
- *Discussion and reflection*: The students engage in knowledge-building discussions and reflection throughout the process.

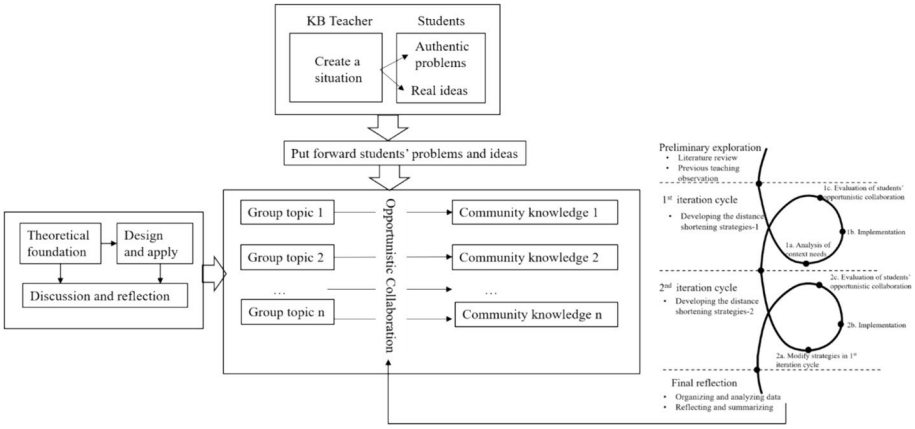


Fig. 2 The research design using DBR with several iteration cycles

Data sources and analysis

In this research, active interaction and KF note quality were two important indicators of whether students were engaging in high-quality opportunistic collaboration. Considering that the teaching environment was a mix of online platforms and offline activities, we collected both online and offline data. The online data were mainly from KF, where the students posted notes and built on each other's ideas. Students' interactions and the content of their notes were recorded and collected every week. The offline data came from video recordings of the weekly class to capture students' movements in the classroom.

To answer the research questions, we examined the effects of students' opportunistic collaboration in each iteration. For the students' online and offline interactions, we applied density analysis to measure whether they were willing to collaborate, and we used clique analysis to measure whether they were collaborating freely and flexibly. To evaluate the quality of students' ideas, we used content analysis. Table 2 shows the coding scheme (Lee et al., 2006). Two researchers coded the students' notes on KF, and the intercoder reliability was computed as 0.86. Generally, a mixed-methods data collection and analysis approach was employed. In addition, a post hoc power analysis was conducted using G*Power, a tool to compute statistical power analyses for t tests (Faul et al., 2009) to determine whether the study had sufficient power to detect a significant effect. The effect size based on Cohen's criteria was 0.8, the sample size was 24, and the significance level was $\alpha = 0.05$. The statistical power was $0.963 > 0.8$. The results indicate that the study had sufficient power to detect a significant effect.

Description of iterations

For the iterations, the physical distance-shortening strategies and the idea distance-shortening strategies were applied in this semester. Physical distance-shortening strategies, namely removing desks and making students closer, are intentional physical configurations that are conducive to sharing and spreading different ideas (Anderson et al., 2017; Brown & Di

Table 2 Coding scheme for the quality of students' ideas (Lee et al., 2006)

Dimension	Description	Rating
The depth of questioning	Questions on definitions and simple clarification	1
	Questions asking for factual, topical and general information	2
	Questions identifying specific gaps and asking for open-ended responses and different viewpoints	3
	Explanation-based questions—Focus on problems not topics; identifies sources of inconsistencies; generates conjectures and possible explanations	4
The depth of explanation	Repeat or simple restate a fact or a statement that has been made	1
	Give factual information and general description; responses are usually centered on facts and topics; cut and paste; is used rather than making own interpretations	2
	Give responses and make inferences supported with some relevant information	3
	Make assertions supported with explanation, evidence and relevant examples	4
	Refocus discussion or highlight key conceptual issues for further inquiry; bring out other aspects of issues for discussion	5
	Recognize high points in discourse; metacognitive, show personal reflection	6
	Synthesize different points of views and make a rise-above summary	7

Lallo, 2020), which make students' ideas closely connected. In other words, students' idea distance is influenced by their physical distance to some extent. The first and second iterations actually improve students' opportunistic collaboration from two related aspects that are concerned with distance shortening.

Shortening students' physical distance

To help students accept and enter opportunistic collaboration, we addressed the KB principle of community knowledge and collective responsibility and encouraged students to share their ideas with the whole class. Thus, the first iteration focused on environmental settings, providing a safe and free learning environment that facilitated opportunistic collaboration. To encourage the students to leave their seats and start to collaborate with different people, we made the physical space more flexible: all desks and chairs in the classroom were equipped with wheels so that the students could easily combine different tables as they wished and form new group discussions as well as join in other group discussions freely.

However, we found that only a few students participated freely in discussions after this intervention. Most of the students still gathered based on their old groups. They did not care about others' ideas, indicating that this intervention did not help much. We observed that the students tended to sit around desks and not move when the teacher asked them to start discussing material, thus collaborating based only on the desk where they were originally sitting. Thus, we speculated that having desks in the classroom might be a barrier for students to move around and mislead them to form groups even when we intend to engage them in idea-centered rather than group-centered collaboration. The next week, we removed all the desks and left only the chairs in an attempt to break the barriers formed by fixed groups.

In addition, a knowledge-building circle, a live discussion held in a circle, was used to make the learning environment more free-flowing and enlarge the scope of interaction. The idea of the knowledge-building circle can be traced back to the talking circles of indigenous American cultures, in which individuals take turns sharing ideas. Sitting in a circle can facilitate students' face-to-face dialog. Body language, such as eye contact, is thus visible, making it easier for the participants to show each other respect and engage in active listening (Anderson et al., 2017). Thus, the connection among students can be enhanced.

After the first iteration, we carefully observed students' online and offline interactions. It was obvious that after the desks were removed, most of the students had to leave their fixed position and observe the topics of discussion across the whole class. The intensity of offline discussion was quite high, which indicated that the students gradually engaged in opportunistic collaboration. Although the approach to building a free and flexible learning environment increased the chances of offline opportunistic collaboration, the students' online interaction remained shallow. There were many related notes that should have been connected to generate more discussions and expand their scope, but the students were not aware of those connections and missed opportunities for opportunistic collaboration; as a result, the online intensity was low. For instance, one student mentioned the pros of learning analytics, and other students mentioned the cons of learning analytics. These two notes were closely related, but no connections were drawn between them. Numerous isolated notes were found on KF, indicating that the students' online opportunistic collaboration was insufficient. There were still a considerable number of notes that were not seen by the whole class.

Overall, the intervention in the first iteration focused on the environmental conditions of the offline learning space, which shortens students' physical distance and aims to gradually transform fixed-group collaboration into more flexible collaboration in which students freely move around in the classroom. The attempts to engage students in offline opportunistic collaboration worked, although engaging them in online opportunistic collaboration and fostering deep opportunistic collaboration required the development of additional teaching strategies. Therefore, in the next iteration, the pedagogical intervention was aimed at making students aware that more connections could be drawn among their different ideas.

Shortening students' idea distance

The first iteration focused on shortening students' physical distance, with the consequence of students starting flexible collaboration in the class while the quality of the discourse is not high. Therefore, the second iteration focused mainly on engaging students in deep opportunistic collaboration and widening their online and offline interactions by shortening students' idea distance.

We used the knowledge-building Discourse Explorer (KBDeX) tool to help the students understand the relationships among different notes. More specifically, KBDeX (http://www.kbdex.net/) is an analytical tool that visualizes discourse network structures based on the co-occurrence of selected keywords in the corpus. It shows the network structure of learners, the network structure of discourse units (usually, a note posted by a learner is regarded as a discourse unit) and the network structure of selected keywords (Oshima et al., 2012). This tool is commonly used by teachers and researchers to identify knowledge structures and interaction relations within a learning community (Lee et al., 2016). In this study, we encouraged the students to use it.

First, we used KBDeX to automatically generate keyword maps and student interaction structure maps based on students' notes on KF. Second, the teacher started to guide the students toward the idea that there were connections among their different notes. For instance, the teacher mentioned that some students were investigating the assessment of informal learning on KF, while others were designing teaching cases for informal learning. Thus, the question of how to verify the effectiveness of the design was raised. The students started to think about combining these two inquiry topics, and the members of these two groups had in-depth conversations. Then, the teacher distributed the learner interaction structure maps and keyword structure maps to each student and taught them how to use the maps. For example, all the balls and their connections in Fig. 3 represent the keyword structure of the whole class at that time, while Fig. 4 represents the student relation structure. When the students clicked S6, S13, S16, S2, S4, and S17 in Fig. 4 (shown as red balls), a special keyword structure map that consisted of red balls (shown in Fig. 3) appeared, which was exactly the keyword map of S6, S13, S16, S2, S4 and S17. In this way, the students could easily understand their inquiry topics and structures. Moreover, they could expand their inquiries by referencing the keywords in yellow balls that were close to their own keyword maps, as this indicated topics they had not thought of. Students who wanted to explore interesting topics could also click a keyword in the keyword structure map and turn to the interaction map to easily find other students who were talking about that topic. Overall, this teaching strategy helped students become aware of the connections among different ideas and created chances for them to engage in opportunistic collaboration.

Fig. 3 Knowledge structure map

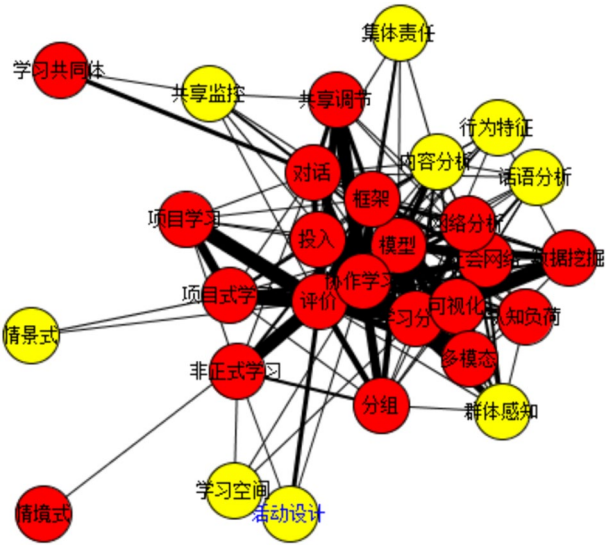


Fig. 4 Interaction map

In addition to using KBDeX, we simulated several academic poster sessions for students. They introduced their inquiry procedures, and each student was asked to bring a marker and sticky notes to comment on different groups' inquiry projects.

In the subsequent class discussion, the teacher observed that the students' ideas developed quickly. The node connections on KF increased. In the offline activities, the students started to realize the relationships among their ideas. For instance, the following conversation took place:

S1: These five points should be considered when designing reasonable strategies to improve the efficiency of informal learning.
S2: What do you think about these five points? I remember that C has an opinion on the factors influencing informal learning; maybe you should compare your ideas with C's opinion.
S1: Exactly. Then, I will find a better way to design my teaching strategies.

These two rounds of iteration revealed constant changes and developments in opportunistic collaboration, indicating that students have the potential to engage in deep opportunistic collaboration.

Results

After one semester of intervention and data collection, several findings emerged based on video analysis, social network analysis and content analysis.

Online and offline density

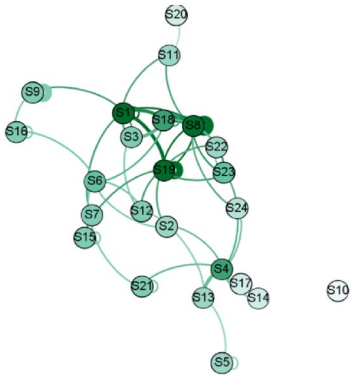
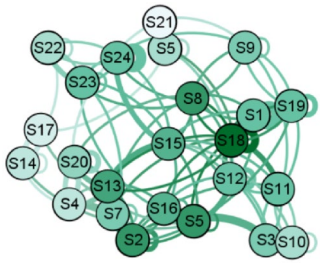
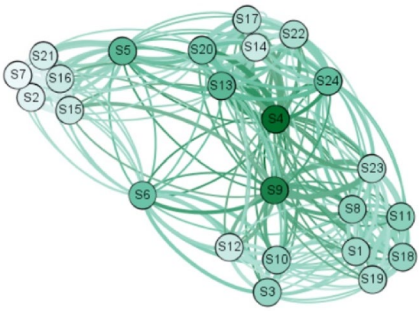
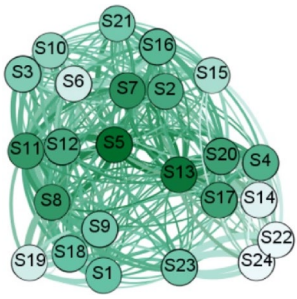
After two iterations, the students' online and offline interactions changed considerably. We recorded and examined their movements in the classroom and their interaction density every week to determine how they changed. To compare students' movements in the two iterations, we used the number of student movements divided by the duration of the iteration to eliminate the interference of the duration of each iteration cycle. Then, we conducted a paired-sample t test to compare students' movements in the first and second iterations. The results indicated that the average number of movements per unit of time was significantly higher in the second iteration ($M = 0.085843$) than in the first iteration ($M = 0.014163$) ($t = -9.846$, $df = 23$, $p = 0.000 < 0.05$), which indicated that the barriers and boundaries for students to engage in opportunistic collaboration had been gradually eliminated.

We also built online and offline student interaction matrices from KF and video records, respectively. Then, the interaction data were imported into Gephi, and the intensity was calculated as shown below (see Table 3). The offline interaction structure gradually became tighter, and the density increased. The online interaction structure and density had the same trend as the offline interaction structure and density, leading us to infer that the students were motivated to participate in opportunistic collaboration.

Online and offline grouping

To illustrate whether students changed from fixed-group collaboration to opportunistic collaboration with flexible grouping, we used clique analysis based on K-plex and set an appropriate K value = 1; minimum set size = 3. Under the same K value setting, the online and offline grouping situations in the first and second iterations were totally different. Figure 5 presents the students' online/offline grouping situation in the first and second iterations. The results showed that students were able to collaborate freely and flexibly, especially in the second iteration, as there were 32 online groups and 85 offline groups in the second iteration, while there were only 6 online groups and 17 offline groups in the first

Table 3 Interaction structure and density

	The first iteation	The second iteration
Online interaction structure		
Density	0.101	0.205
Offline interaction structure		
Density	0.464	0.582

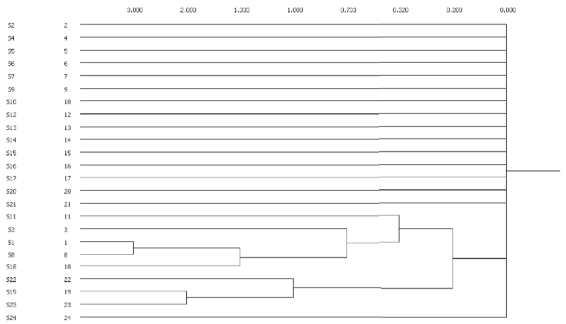
iteration. We inferred that the students gradually became accustomed to opportunistic collaboration.

Moreover, we found that although group members changed constantly, some groups remained fixed. For instance, offline group 3 in the first iteration consisted of S1, S4, S8, S9, S11, S18, S23, and S24, while offline group 17 consisted of S1, S5, S8, S9, S11, S12, S18, and S19. There were some overlapping members. The fixed but also free grouping situation at 12 weeks indicated that the students had started to engage in deeper and more targeted collaboration with specific members; thus, we inferred that the intervention strategies aimed at engaging students in deep opportunistic collaboration were effective for deep knowledge-building processes.

Depth of students' ideas

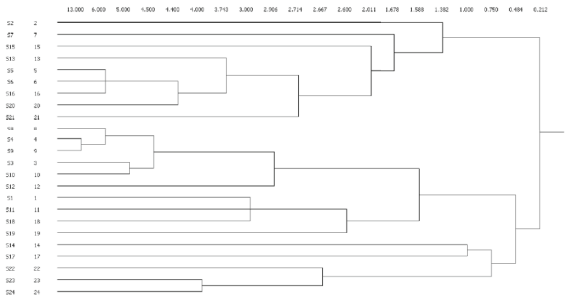
To verify whether the students' learning and inquiry quality improved, we conducted content analysis. Then, we applied a paired-sample *t* test. The results are shown in Tables 4 and 5.

The results showed that the depth of the students' inquiries gradually improved ($M1 = 2.9113$; $M2 = 3.4663$), and there was a statistically significant difference between



Group1: S1 S3 S18
Group2: S1 S8 S11
Group3: S1 S8 S18
Group4: S1 S8 S19
Group5: S8 S19 S23
Group6: S19 S22 S23

(a) Online grouping situation in the first iteration



Group1: S1 S3 S4 S8 S9 S10 S11 S18 S19
Group2: S1 S4 S8 S9 S11 S18 S19 S23
……
Group15: S4 S9 S13 S22 S23 S24
Group16: S5 S6 S7 S15 S16 S20 S21
Group17: S5 S6 S13 S16 S20 S21

(b) Offline grouping situation in the first iteration

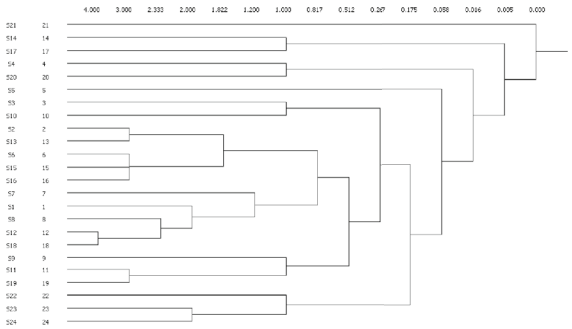
Fig. 5 Students' online/offline grouping situation

the first and second iterations (t = -2.765, df = 23, p = 0.011 < 0.05). The depth of explanation was much higher in the second iteration than in the first iteration ($M1$ = 3.3754; $M2$ = 4.3146), and there was a statistically significant difference between the first and second iterations (t = -3.953, df = 23, p = 0.001 < 0.05).

Discussion and conclusion

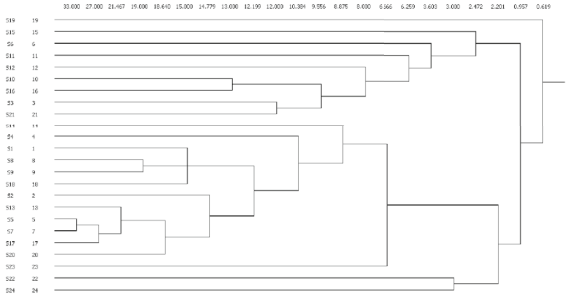
Taken as a whole, this research highlighted the knowledge-building principle of "community knowledge, collective responsibility" that required the participants to work collaboratively as a knowledge creation community (Scardamalia, 2002) and demonstrated how a DBR approach can be used to iteratively design strategies to engage students in opportunistic collaboration and knowledge creation culture. To this end, two iterative design cycles were implemented in a knowledge-building environment. The preliminary data suggest that using distance-shortening strategies is feasible for changing the collaboration behaviors and attitudes of university students who are used to traditional learning, with positive impacts on the outcomes.

In terms of the outcomes, during these two iteration cycles, the students' collaboration habits progressively changed from group-centered to idea-centered, and these iterations increased students' opportunities for knowledge creation and improved the quality of the knowledge-building process. In the first iteration cycle, we found that the students



Group1: S1 S6 S15
Group2: S1 S6 S18
Group3: S1 S8 S15
Group4: S1 S8 S18
……
Group29: S13 S15 S16
Group30: S13 S16 S18
Group31: S15 S16 S23
Group32: S22 S23 S24

(c) Online grouping situation in the second iteration



Group1: S1 S2 S4 S5 S13 S17 S20
Group2: S1 S2 S4 S5 S17 S18 S20
Group3: S1 S2 S5 S8 S9 S11 S18
……
Group17: S1 S5 S8 S9 S11 S12 S18 S19
Group18: S1 S5 S8 S9 S11 S18 S19 S23
……
Group84: S7 S9 S14 S17 S18 S23
Group85: S7 S10 S14 S16 S17 S20
Group86: S7 S15 S22 S23 S24

(d) Offline grouping situation in the second iteration

Fig. 5 (continued)

Table 4 Statistics of students' inquiry quality in the first and second iterations (paired sample statistics)

	M	N	SD	Std. error mean
Depth of questioning				
#in the first iteration	2.9113	24	.85752	.17504
#in the second iteration	3.4663	24	.59659	.12178
Depth of explanation				
#in the first iteration	3.3754	24	.76361	.15587
#in the second iteration	4.3146	24	.95370	.19467

were able to gradually break the fixed-group boundaries, move around, and talk with each other due to the changes in the environment and facilities, which indicated that the physical distance shortening strategies, removing all the desks and holding a knowledge-building circle, as elaborated in this study, offer a straightforward way for students who are used to group-based collaboration to break the ice and start becoming involved in opportunistic collaboration. As a key element of the knowledge building process, to create a safe and appropriate environment, especially in the initial efforts to create a KB community classroom (Bielaczyc & Ow, 2014), there is a need to remove physical obstacles and give students enough freedom as well as establish in them a sense of security that they can walk around and talk about their ideas with anyone anywhere in

Table 5 Paired Differences of students' inquiry quality in the first and second iterations (paired sample test)

	M	SD	Std. error mean	95% Confidence Interval of the Difference		*t*	df	Sig. (2-tailed)
				Lower	Upper			
Pair 1—Depth of questioning between the first and second iteration	−.55500	.98326	.20071	−.97020	−.13980	−2.765	23	.011
Pair 2—Depth of explanation between the first and second iteration	−.93917	1.16384	.23757	−1.43061	−.44772	−3.953	23	.001

the classroom; these changes allow students to overcome their major barriers, which are the dependency for traditional classroom settings and a fixed-group collaboration configuration as well as a task-oriented culture (So et al., 2010). Physical distance-shortening strategies create an atmosphere in the whole classroom that is flexible enough to support students' self-regulated inquiry work (O'Connor, 2012); such strategies also help students work collaboratively as a whole community rather than in isolated groups. Therefore, in the first iteration, we tended to focus more on the online and offline collaboration action at the shallowest level, which requires students to have open and free collaboration even without a specific reason and embodies the nature of free and sufficient communication in the knowledge-building community. This can be an important way to help students overcome their initial adherence to traditional fixed-group collaboration habits.

In the second iteration cycle, we found that the students engaged in much deeper and more thorough opportunistic collaboration with higher interaction density and in-depth collaboration quality when personal and community knowledge structures and idea diffusion were suggested as a way to enhance students' awareness of idea relevance and therefore shorten the distance of their ideas, as well as increase the idea diversity and richness. In other words, the idea distance-shortening strategies provide a framework for students to make sense of what is going on in their community (Hutchison & Hammer, 2010; Zhang et al., 2022), focus on the ongoing idea flow (Zhang et al., 2018), plan for deeper inquiries, and make collective contributions. In the meantime, under a flexible and unlimited collaborative environment, students can expand and even reframe their collective work and adjust their inquiry goals. Therefore, a deep level of opportunistic collaboration not only affects the interaction density and students' movements but also students' initiative to continually explore new ideas and transform knowledge-building work far beyond the existing expectations and boundaries (Tao & Zhang, 2021).

In conclusion, this study presents a comprehensive picture of opportunistic collaboration in a knowledge-building environment and offers a lens on collaborative knowledge-building activities. Generally, opportunistic collaboration is commonly seen in organizational innovation and communication research areas (Defillippi et al., 2006; Gloor,

2006). It is a broad notion that includes almost all unplanned and accidental collaboration. It is defined only in terms of collaboration configuration and does not stress collaboration motivation or quality (Kraut et al., 1990; Moreno et al., 2003). However, a more specific definition of opportunistic collaboration is needed in the knowledge-building community, where community knowledge, knowledge democratization and collective responsibility are also highlighted (Zhang et al., 2009, 2022). Opportunistic collaboration in the knowledge-building environment emerges mainly in free discussions in the class and on the online KF with the aim of meeting the curriculum goals and abiding by the principles of knowledge building (Siqin et al., 2015). Promoting students' opportunistic collaboration is a systematic and complex process that involves gradually removing students' physical and mental obstacles and encouraging the idea-centered view of deep exploration.

As implications for educational practices, this research showcases a set of design strategies, which are distance-shortening strategies, to foster opportunistic collaboration in a way that develops students' collaborative ability to face future interconnected worlds. The teacher engages students as knowledge workers to decide who to collaborate with and how the collaborative inquiry unfolds. Unlike fixed-group collaboration with prescriptive collaborative scripts, opportunistic collaboration implies "collaborating for emergence" (Zhang et al., 2022). The teacher can first provide students an authentic and interesting situation as an entry point and provide them with open space without any physical barriers, encouraging them to propose diverse questions and ideas. Then, as students become more open-minded and are allowed to walk around freely in the classroom, participating in open discussion, the teacher can capture students' emergent and promising ideas (e.g., ideas that most students are interested in or conflicting ideas) and organize activities, such as knowledge-building circles, to reinforce students' interaction and make the learning environment more free-flowing. After students gradually become accustomed to flexible collaboration and frequent interaction, teachers can try to deepen students' ideas by visualizing the discourse network structures of the whole community and each student, making them understand the relation of different ideas. This intervention provides students with a guidance framework to carry out purposeful inquiry and deep opportunistic collaboration, informing them about who to collaborate with and what they should investigate. As knowledge work continues, more new ideas are generated, making the discourse network structures increasingly complex and interconnected and leading to more opportunities for deep-level opportunistic collaboration. The teacher needs to be an acute observer of what students are talking about and how ideas flow and engage students in the process of knowledge creation and progressively cultivating a culture of innovation (Cunha & Magni, 2015). Currently, educational reform focuses on developing students' ability to succeed in the future. As such, the distance-shortening strategies proposed in this research provide fundamental guidance for carrying out collaborative activities in knowledge-building communities and other knowledge creation organizations.

This study has some limitations. Cultivating a culture of opportunistic collaboration and innovation is a long-term process. In this research, the instruction lasted for 12 weeks of in-person activities, which may not be enough. More future research needs to be conducted based on the results of this research. In addition, given the small sample size, more research is needed to confirm the results and expand on this current work. However, the evidence herein suggests the potential for students to become accustomed to knowledge-building culture. Finally, students at different stages of learning could be included in future research to improve the generalizability of these results.

Appendix 1

A Brief Introduction of the 12 Knowledge-building Principles (Scardamalia, 2002; Scardamalia & Bereiter, 2010).

- *Real ideas, authentic problems*: Students explore problems and ideas because of genuine concern and curiosity about the real world. The problems and ideas are relevant to their daily life.
- *Idea diversity*: Students think from multiple perspectives and learn from diverse perspectives.
- *Improvable ideas*: All ideas can be continuous improved for community knowledge advancement. Students strive for the refinement of ideas.
- *Rise above*: Deepening and working towards higher level of the discussion as well as starting new and different direction of discussion.
- *Community knowledge, collective responsibility*: Community members share collective cognitive responsibility for advancing ideas to the community.
- *Pervasive knowledge building*: Knowledge building is not limited to a specific place, such as classrooms. It can be in every corner of the school and even out of the school.
- *Democratizing knowledge*: Every student has an equitable opportunity to participate in knowledge-building activities.
- *Symmetric knowledge advancement*: Distributed inner-outer community expertise is highly valued in knowledge-building community, which extends more opportunities to generate ideas.
- *Epistemic agency*: Students are expected to take the initiative to study. They take charge of their own learning process.
- *Knowledge-building discourse*: Fostering students' deep intellectual advancement through deep discussion, opinion exchanges and idea building-on.
- *Constructive uses of authoritative sources*: Students are supposed to use reliable reference materials appropriately to facilitate knowledge building.
- *Concurrent, embedded, transformative assessment*: Assessment is integral to knowledge advancement, with self-directed and self-initiated productive assessment as work proceeds.

Acknowledgements We extend special thanks to Dr. Donald Philip for helping us with editing and revising the first draft. We are thankful to professor Huang-Yao Hong for his comments and suggestions. The first edition of this paper was included in the 25th Annual Knowledge Building Virtual Institute.

Funding This research was supported by the Humanities and Social Sciences Youth Foundation, Ministry of Education of the People's Republic of China (22YJC880011).

Data availability The data that support the findings of this study are available from the corresponding author, upon reasonable request.

References

Anderson, D., Comay, J., & Chiarotto, L. (2017). *Natural curiosity 2nd edition: A resource for educators: Considering indigenous perspectives in children's environmental inquiry*. The Laboratory School at the Dr Eric Jackman Institute of Child Study, Ontario Institute for Studies.

Aronson, E., Blaney, N., Stephen, C., Sikes, J., & Snapp, M. (1978). *The jigsaw classroom*. Sage.

Barab, S. (2014). Design-based research: A methodological toolkit for engineering change. In R. K. Sawyer (Eds.), *The Cambridge handbook of the learning sciences* (pp.151–170). Cambridge University Press. https://doi.org/10.1017/cbo9781139519526.011

Bereiter, C. (2005). Education and mind in the knowledge age. *Routledge*. https://doi.org/10.4324/9781410612182

Bielaczyc, K., & Ow, J. (2014). Multi-player epistemic games: Guiding the enactment of classroom knowledge-building communities. *International Journal of Computer-Supported Collaborative Learning, 9*(1), 33–62. https://doi.org/10.1007/s11412-013-9186-z

Braniff, C. (2011). Perceptions of an active classroom: exploration of movement and collaboration with fourth grade students. *Networks: an Online Journal for Teacher Research, 13*(1), 1–6.

Brown, M. A., & Di Lallo, S. (2020). Talking circles: A culturally responsive evaluation practice. *American Journal of Evaluation, 41*(3), 367–383. https://doi.org/10.1177/1098214019899164

Cacciamani, S. (2010). Towards a knowledge building community: From guided to self-organized inquiry. *Canadian Journal of Learning and Technology/La Revue Canadienne de l'apprentissage et de La Technologie, 36*(1). https://doi.org/10.21432/t27599

Chang, W., & Benson, V. (2020). Jigsaw teaching method for collaboration on cloud platforms. *Innovations in Education and Teaching International, 59*(1), 24–36. https://doi.org/10.1080/14703297.2020.1792332

Chatzkel, J. L. (2003). Knowledge capital: How knowledge-based enterprises really get built. *Oxford University Press*. https://doi.org/10.1093/oso/9780195161144.001.0001

Chen, Y. (2022). *Opportunistic collaboration in a knowledge building community: Research on promotion mechanism* [Unpublished doctoral dissertation]. Nanjing Normal University.

Cinelli, M., De Francisci Morales, G., Galeazzi, A., Quattrociocchi, W., & Starnini, M. (2021). The echo chamber effect on social media. *Proceedings of the National Academy of Sciences, 118*(9), e2023301118. https://doi.org/10.1073/pnas.2023301118

Cunha, M. P. E., & Magni, M. (2015). Management improvisation. In G. Ritzer (Eds.), *The Blackwell Encyclopedia of sociology* (pp.2733–2736). Blackwell Publishing. https://doi.org/10.1002/9781405165518.wbeosm016.pub2

De Wever, B., Schellens, T., Van Keer, H., & Valcke, M. (2008). Structuring asynchronous discussion groups by introducing roles: Do students act in line with assigned roles? *Small Group Research, 39*(6), 770–794. https://doi.org/10.1177/1046496408323227

Defillippi, R. J., Arthur, M. B., & Lindsay, V. J. (2006). *Knowledge at work: Creative collaboration in the global economy.* Blackwell Publishing. https://doi.org/10.1111/j.1467-9310.2007.00475_2.x

Engeström, Y. (2008). *From teams to knots: Activity-theoretical studies of collaboration and learning at work*. Cambridge University Press. https://doi.org/10.1017/cbo9780511619847

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149–1160. https://doi.org/10.3758/brm.41.4.1149

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: computer conferencing in higher education. *Internet and Higher Education, 2*(2–3), 87–105. https://doi.org/10.1016/S10967516(00)00016-6

Gloor, P. A. (2006). Swarm creativity. *Oxford University Press*. https://doi.org/10.1093/acprof:oso/9780195304121.001.0001

Goldenberg, O., Larson, J. R., & Wiley, J. (2013). Goal instructions, response format, and idea generation in groups. *Small Group Research, 44*(3), 227–256. https://doi.org/10.1177/1046496413486701

Gorelick, C., Milton, N., & April, K. (2004). *Performance through learning: Knowledge management in practice*. Elsevier Inc. https://doi.org/10.1016/b978-0-7506-7582-6.50005-4

Granovetter, M. S. (1977). The strength of weak ties. In *Social networks* (pp. 347–367). https://doi.org/10.1016/b978-0-12-442450-0.50025-0

Handy, C. (1989). *The age of unreason*. Arrow Business Books.

Hargreaves, A. (1994). *Changing teachers, changing times: Teachers' work and culture in the postmodern age*. Cassell.

Healion, D., Russell, S., Cukurova, M., & Spikol, D. (2017). Tracing physical movement during practice-based learning through multimodal learning analytics. In S. Fraser (Eds), *Proceedings of the*

seventh international learning analytics & knowledge conference (pp. 588–589). ACM. https://doi.org/10.1145/3027385.3029474

Henderikx, M., Beckers, J., Vrieling, E., Evers, A., & Kreijns, K. (2023). Four models and frameworks of computer supported collaborative learning. In T. Bastiaens (Ed.), *Proceedings of EdMedia + innovate learning* (pp. 672–681). Vienna: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/primary/p/222563/

Hoffman, M., & Herrmann, T. (2001). Prospect awareness—Envisioning the benefits of collaborative work. *Research Gate.* Retrieved from https://www.researchgate.net/publication/228608370

Hong, H.Y., Scardamalia, M., & Zhang, J. (2010). Knowledge society network: Toward a dynamic, sustained network for building knowledge. *Canadian Journal of Learning and Technology/La Revue Canadienne de l'apprentissage et de La Technologie,* 36(1). https://doi.org/10.21432/t2mg6p

Hong, H. Y. (2011). Beyond group collaboration: Facilitating an idea-centered view of collaboration through knowledge building in a science class of fifth-graders. *The Asia–pacific Education Researcher, 20*(2), 248–262.

Hong, H. Y., Lin, P. Y., Chai, C. S., Hung, G. T., & Zhang, Y. (2019). Fostering design-oriented collective reflection among preservice teachers through principle-based knowledge building activities. *Computers & Education, 130*, 105–120. https://doi.org/10.1016/j.compedu.2018.12.001

Husain, H., Husain, A., Samad, S. A., & Wahab, D. A. (2013). Jigsaw learning techniques: Addressing problems of implementation. *The Social Sciences, 8*(6), 596–599.

Hutchison, P., & Hammer, D. (2010). Attending to student epistemological framing in a science classroom. *Science Education, 94*, 506–524. https://doi.org/10.1002/sce.20373

Jiang, J., Hu, J., Zhang, Y., & Yin, X. (2022). Fostering college students' critical thinking skills through peer assessment in the knowledge building community. *Interactive Learning Environments*, 1–17. https://doi.org/10.1080/10494820.2022.2039949

Karlgren, K., Paavola, S., & Ligorio, M. B. (2020). Introduction: What are knowledge work practices in education? How can we study and promote them? *Research Papers in Education, 35*(1), 1–7. https://doi.org/10.1080/02671522.2019.1677761

Khalid, K., Woungang, I., Dhurandher, S. K., Singh, J., & Barolli, L. (2021). A fuzzy-based check-and-spray geocast routing protocol for opportunistic networks. *Journal of High Speed Networks, 27*(1), 1–12. https://doi.org/10.3233/jhs-210648

Kirsch-Pinheiro, M., Valdeni de Lima, J., & Borges, M. R. S. (2003). A framework for awareness support in groupware systems. *Computers in Industry, 52*(1), 47–57. https://doi.org/10.1016/s0166-3615(03)00068-x

Kraut, R. E., Fish, R. S., Root, R. W., & Chalfonte, B. L. (1990). Informal communication in organizations: Form, function, and technology. In S. Oskamp & S. Spacapan (Eds.), *Human reactions to technology: Claremont symposium on applied social psychology* (pp. 145–199). Sage.

Lee, V. Y. A., Tan, S. C., & Chee, J. K. K. (2016). Idea Identification and Analysis (I2A): A Search for Sustainable Promising Ideas within Knowledge-Building Discourse. In C. K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Proceedings of 12th international conference of the learning sciences* (pp. 90–96). International Society of the Learning Sciences, Inc.

Lee, E. Y. C., Chan, C. K. K., & van Aalst, J. (2006). Students assessing their own collaborative knowledge building. *International Journal of Computer-Supported Collaborative Learning, 1*(1), 57–87. https://doi.org/10.1007/s11412-006-6844-4

Lewin, K. (1951). *Field theory in social science*. Harper & Brothers.

Lin, P.-Y., Hong, H.-Y., & Chai, C. S. (2019). Fostering college students' design thinking in a knowledge-building environment. *Educational Technology Research and Development, 68*(3), 949–974. https://doi.org/10.1007/s11423-019-09712-0

McKenney, S., & Reeves, T. (2018). *Conducting Educational Design Research* (2nd edn.). Routledge. https://doi.org/10.4324/9781315105642

Moreno, M., Vivacqua, A., & Souza, J. D. (2003, Sept). An agent framework to support opportunistic collaboration. In J. Favela, & D. Decouchant (Eds.), *Lecture notes in computer science* (pp. 224–231). Springer. https://doi.org/10.1007/978-3-540-39850-9_20

Naeve, A. (2010). Opportunistic (L)earning in the mobile knowledge society. *International Journal of Mobile and Blended Learning, 2*(4), 29–46. https://doi.org/10.4018/jmbl.2010100103

O'Connor, D. (2012). *A pedagogy of freedom: Why primary school teachers should embrace educational emancipation*. ResearchOnline@ND. Retrieved from https://researchonline.nd.edu.au/edu_conference/75/

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge building discourse explorer: A social network analysis application for knowledge building discourse. *Educational Technology Research and Development, 60*(5), 903–921. https://doi.org/10.1007/s11423-012-9265-2

Perritano, A., Moher, T. (2019). Knowledge places: Embedding knowledge in the space of the classroom. In *IDC '19 Proceedings of the 18th ACM international conference on interaction design and children* (pp. 598–603). Association for Computing Machinery. https://doi.org/10.1145/3311927.3325326

Popper, K. R. (1972). *Objective knowledge: An evolutionary approach*. Oxford University Press.

Reilly, J. M., Ravenell, M., & Schneider, B. (2018). Exploring Collaboration Using Motion Sensors and Multi-Modal Learning Analytics. In K. E. Boyer, & M. Yudelson (Eds.), *Proceedings of the 11th international educational data mining* (pp.333–339). International Educational Data Mining Society.

Root, R. W. (1988). Design of a multi-media vehicle for social browsing. In *Proceedings of the 1988 ACM conference on computer-supported cooperative work* (pp. 25–38). Association for Computing Machinery. https://doi.org/10.1145/62266.62269

Rutten, R. (2017). Beyond proximities: The socio-spatial dynamics of knowledge creation. *Progress in Human Geography, 41*(2), 159–177. https://doi.org/10.1177/0309132516629003

Sawyer, K. (2003). *Emergence in creativity and development*. Oxford University Press.

Sawyer, K. (2007). *Group genius: The creative power of collaboration*. NY: Basic Books.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Open Court.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. In J. W. Guthrie (Ed.), *Encyclopedia of education* (pp. 1370–1373). Macmillan Reference.

Siqin, T., Van Aalst, J., & Chu, S. (2013). Examining dynamics of implementing flexible group discourse in a principle-based CSCL environment. In N. Rummel, M. Kapur, M. Nathan, & S Puntambekar (Eds.), *To see the world and a grain of sand: learning across levels of space, time, and scale: CSCL 2013 conference proceedings volume 1—Full papers & symposia* (pp.446–453). International Society of the Learning Sciences (ISLS).

Siqin, T., Van Aalst, J., & Chu, S. (2015). Fixed group and opportunistic collaboration in a CSCL environment. *International Journal of Computer-Supported Collaborative Learning, 10*(2), 161–181. https://doi.org/10.1007/s11412-014-9206-7

So, H.-J., Seah, L. H., & Toh-Heng, H. L. (2010). Designing collaborative knowledge building environments accessible to all learners: Impacts and design challenges. *Computers & Education, 54*(2), 479–490. https://doi.org/10.1016/j.compedu.2009.08.031

Stahl, G. (2000). A model of collaborative knowledge-building. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth International Conference of the Learning Sciences* (pp. 70–77). Mahwah, NJ: Erlbaum.

Stahl, G. (2013). Learning across levels. *International Journal of Computer-Supported Collaborative Learning, 8*, 112. https://doi.org/10.1007/s11412-013-9169-0

Tang, M., Qi, Y., & Zhang, M. (2017). Impact of product modularity on mass customization capability: An exploratory study of contextual factors. *International Journal of Information Technology and Decision Making, 16*(4), 939–960. https://doi.org/10.1142/s0219622017410012

Tao, D., & Zhang, J. (2021). Agency to transform: How did a grade 5 community co-configure dynamic knowledge building practices in a yearlong science inquiry? *International Journal of Computer-Supported Collaborative Learning, 16*, 403–434. https://doi.org/10.1007/s11412-021-09353-7

Tian Y, Zhang J. (2017). Tracing the Inquiry of an Opportunistic Group in a Grade 5 Knowledge Building Community. KBSI 2017. Retrieved from http://ikit.org/kbsi2017/Papers-Posters/KBSI2017-Tian-Zhang.pdf

Trope, Y., & Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review, 117*(2), 440–463. https://doi.org/10.1037/a0018963

Wu, Y.-T., & Wang, L.-J. (2023). Advancing university EFL students' argumentative essay writing performance through knowledge-building-based holistic instruction. *Educational Technology & Society, 26*(3), 115–128. https://doi.org/10.30191/ETS.202307_26(3).0009

Yu, A. T. W. (2017). Using jigsaw method to enhance the learning of research and consultancy techniques for postgraduate students. *Engineering, Construction and Architectural Management, 24*(6), 1081–1091. https://doi.org/10.1108/ecam-03-2016-0080

Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge-building communities. *Journal of the Learning Sciences, 18*(1), 7–44. https://doi.org/10.1080/10508400802581676

Zhang, J., Tao, D., Chen, M. H., Sun, Y., Judson, D., & Naqvi, S. (2018). Co-organizing the collective journey of inquiry with idea thread mapper. *Journal of the Learning Sciences, 27*(3), 390–430. https://doi.org/10.1080/10508406.2018.1444992

Zhang, J., Tian, Y., Yuan, G., & Tao, D. (2022). Epistemic agency for costructuring expansive knowledge-building practices. *Science Education, 106*(4), 890–923. https://doi.org/10.1002/sce.21717

Yujie Chen is a lecturer in the School of Teacher Education at Huzhou University. She received Ph.D. degree from Nanjing Normal University. Her research interests focus on learning sciences, collective intelligence and knowledge building as well as the mechanism on collaborative learning to sustain knowledge innovation.

Yibing Zhang is a professor in the School of Education Science at Nanjing Normal University. His research interests focus on educational technology, learning sciences, computer-supported collaborative learning and knowledge building.