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Advancing third graders' reading comprehension through collaborative Knowledge Building: A comparative study in Taiwan

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ABSTRACT

In the digital age, reading literacy, and particularly, higher-level reading comprehension involved in making sense of information from multiple sources online is an important educational challenge. This study explores designs for teaching reading to third graders in Taiwan. Over the course of a semester, the experimental group engaged in an innovative technology-supported approach called Knowledge Building (KB), while the comparison group engaged in the traditional approach of direct instruction. Statistical analyses reveal that students in the KB class outperformed their counterparts on the PIRLS reading assessment at the end of the semester. Additional quantitative and qualitative analyses indicate that the use of Knowledge Forum technology in the KB class supported the development of higher-level reading comprehension skills through sustaining creative, collaborative work with ideas. Implications for teaching new literacies and digital competencies in computer-supported collaborative learning environments are discussed.

1. Introduction

One of the core functions of reading literacy is to support the development of one's knowledge and understanding of the world around them. Reading comprehension – the ability to read, process, and reflect on written text – helps students develop reading skills, mastery of language, critical thinking skills, and core knowledge for progressively more challenging academic work (Kohzadi, Azizmohammadi, & Samadi, 2014). Having excellent reading comprehension skills also increases students' enjoyment and effectiveness of reading (Whitten, Labby, & Sullivan, 2016). More importantly, reading comprehension enables students to express their thoughts, ideas, and feelings, which, in the long run, helps them become active citizens in today's democratic societies (OECD, 2010).

Given its importance as the central task of formal schooling, countries around the world regularly participate in an international comparative assessment for measuring reading comprehension called the Progress in International Reading Literacy Study (PIRLS) as a way to evaluate students' reading competitiveness. Many East Asian countries have been doing fairly well, including Taiwan, which ranked eighth in the 2016 PIRLS test (Mullis, Martin, Foy, & Hooper, 2017). However, as we enter the fourth industrial revolution, rapid growth of Internet technologies and artificial intelligence in all sectors of society bring new challenges and opportunities for reading and working with information (Mullis et al., 2017). For example, Internet bots are now able to perform low-level reading

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comprehension of written texts as well as generate false information online. Policymakers assert that "Educators will be required to support students to develop new digital competencies and literacies, and promote a greater awareness of issues in the digital environment" (UNESCO, 2020, p. 138).

To remain competitive, education systems need to engage in continuous reform to raise the standards for literacy instruction. The Taiwanese government has been encouraging teachers to experiment with new pedagogies for advancing students' reading comprehension (Taiwan Ministry of Education, 2020). This paper investigates the use of an innovative pedagogy called Knowledge Building (KB) in reading education in Taiwan. Knowledge Building is distinguished from other forms of inquiry-based learning by its focus on not only generating ideas, but on continually improving them through progressive discourse (Scardamalia & Bereiter, 2006). It is often regarded as a form of deep constructivism as it is guided by a set of principles rather than procedures – the Knowledge Building principles enable collective inquiry into an expanding range of topics, through interactive questioning, theory development, idea refinement, and rise above explanations (Scardamalia, 2002). In the following sections, we first review a traditional method for teaching reading in Taiwan called direct instruction. Next, we discuss how an idea-centered, principle-based pedagogy such as KB can contribute to reforming reading education in Taiwan. Then we describe the comparative design used in this study to examine the effects of direct instruction and KB pedagogy on young students' PIRLS reading scores. Finally, we present and discuss the findings regarding how KB pedagogy helps enhance young children's reading comprehension and collaborative meaning-making skills.

2. Literature review

2.1. Direction instruction for teaching reading

In East Asian countries, a widely adopted approach to developing young children's reading comprehension is teacher-centered, direct instruction (Lau, 2017). As a generic teaching model, direct instruction is a set of instructional practices that target the development of cognitive skills via explicitly sequenced learning procedures, activities, and structures, including individual tasks, small group tasks, and face-to-face instruction (Carnine, Silbert, Kameenui, & Tarver, 2016; Hollingsworth & Ybarra, 2017). To teach reading efficiently and effectively via direct instruction, teachers must clarify in advance the essential learning objectives as well as the required evaluation procedures and techniques (e.g., presenting lectures and lessons, asking questions to diagnose misconceptions, pacing tasks to keep students motivated and engaged, orchestrating student interactions to maximize the amount of time spent on reading tasks, etc.). Some exemplary procedures for direct instruction for reading include presenting vocabulary of the article; introducing phrases and sentences; summarizing outlines of the article; explaining paragraphs in the article; questioning and evaluating student learning; and guiding students to finish worksheet and questions at the end of each lesson (Carnine et al., 2016).

Research has consistently shown that direct instruction for teaching reading positively impacts students' academic outcomes. In a meta-analysis of the effectiveness of direct instruction (from 1966 to 2016), based on 328 studies (in subject areas including reading, math, language, spelling, and other academic subjects), Stockard, Wood, Coughlin, and Rasplica Khoury (2018) found that except for affective outcomes, all of the estimated effects were positive with statistical significance. In addition, direct instruction is effective for teaching reading to young children (Wright, Fugett, & Caputa, 2013), as well as students from at-risk populations, including low-achieving students (Viadero, 2002), students with special needs (Crowley, McLaughlin, & Kahn, 2013; Kamps et al., 2016), and second language learners (Van Staden, 2011). Nevertheless, more recent work calls into question the depth of learning achieved through direct instruction. In a review of 40 reading studies targeting K-5 students, Eppley and Dudley-Marling (2018) reveal that the majority of positive effects reported from direct instruction are based on word-level measures of reading. Moreover, when it comes to reading comprehension, students receiving direct instruction still perform at low levels of conceptual understanding. As a result, direct instruction may promote shallow reading strategies, while stunting students' relationship with reading. New approaches to reading instruction are needed to provide students with opportunities to take ownership over the reading comprehension process.

New information and communication technologies (ICT), such as smart phones and other Internet-enabled mobile devices, have made online reading (or e-reading) an inevitable part of students' daily lives (Le Bigot & Rouet, 2007). Nowadays, it is common for students to navigate search engines, sift through multiple webpages, and participate in online chatrooms and forums to exchange ideas and information (Leu, Kinzer, Coiro, & Cammack, 2004). Such digital competencies and literacies go beyond reading and comprehending information online toward finding productive ways of working with information and others online. Thus, a contemporary challenge for reading and literacy education is engaging students in sustained collaborative work with ideas toward enriching collective understanding in complex learning environments that blend written texts, books, online articles and other forms of digital media (Goldman & Scardamalia, 2013; Resta & Laferrière, 2007). Since online reading, and more specifically, reading comprehension derived from multiple sources, is increasingly important, this study aims to design a computer-supported collaborative learning environment to help elementary students read and comprehend reading materials online, with socio-technological supports for constructing meaning, making inferences, and integrating and evaluating information.

2.2. Knowledge Building pedagogy and technology for enhancing reading

While research indicates direct instruction is an effective strategy for teaching reading, there are concerns about its use in contemporary education. First, direct instruction was initially developed within a zeitgeist where learning was predominantly viewed as an individual rather than a collaborative endeavor (Bereiter & Engelmann, 1966; Engelmann, 1980). In the age of digital technologies and networked societies (Castells, 2011), however, collaborative reading and meaning-making of texts and multimedia online is an inevitable reality (Lankshear & Knobel, 2011; The New London Group, 1996). Consequently, computer-supported collaborative

learning represents an increasingly important approach for advancing classroom practices (Chen & Chen, 2014; Johnson, Archibald, & Tenenbaum, 2010; Yang, Zhang, Su, & Tsai, 2011). Second, online environments provide affordances for students to actively work with diverse resources and tools to support their reading that they would otherwise not have access to when reading from a single print source. A study comparing reading comprehension between the two modes of reading (digital vs. print) found that students were more likely to utilize multiple reading resources (e.g., dictionary, thesaurus, word pronunciation) when reading digital text than print text (Wright et al., 2013). Third, direct instruction is often associated with better teaching effects on basic knowledge and low-level reading skills that are deemed important for passing conventional standardized tests (Johnson, 2019; Lau, 2017), rather than for developing higher-level critical thinking and reading skills – skills that are increasingly needed for the fourth industrial revolution (World Economic Forum, 2016).

According to UNESCO (2014), at the current rate of adoption of Internet technologies, nearly all of the world's population will have access in just a few years. Previous research also indicates the importance of multi-literacies as a pedagogical approach to making classroom teaching more inclusive of linguistic and technological diversity (Lankshear & Knobel, 2011; The New London Group, 1996). In the meantime, Taiwan is also undergoing reform to promote the simultaneous development of multiple literacies (e.g., reading, writing, technology) via the use of digital technologies (Ke, Chang, Chan, & Chiu, 2017). Several innovative technology-enhanced pedagogies, like Knowledge Building (KB) pedagogy, have been introduced in schools to improve students' reading comprehension. Unlike direct instruction, which emphasizes top-down curriculum design and prescribed behavioral scripts for teaching (Winograd & Hare, 1988), Knowledge Building takes an idea-centered, principle-based approach for teaching (Scardamalia & Bereiter, 2010) with the aim of empowering students to assume collective responsibility for idea improvement. The teacher engages students in discussions centered around their initial ideas to progressively improve their ideas through the creation of community knowledge (Scardamalia, 2002). Of all the important KB principles developed and evolved over the past 30 years (Chen & Hong, 2016; Scardamalia, 2002), perhaps the most directly related to *working with ideas* in design mode are: (1) Real Ideas and Authentic problems—students are given autonomy to identify problems of understanding from their reading and collaboratively *produce ideas* to address their problems; (2) Idea Diversity—students freely *exchange and share diverse ideas* in a judgement-free space to drive knowledge advancement; (3) Improvable Ideas—ideas produced from the reading (including students' and experts' ideas) should be regarded as improvable and efforts from the community should focus on improving the quality, coherence, and utility of ideas through sustained *idea elaboration and integration*; (4) Rise Above—students work progressively with ideas through *idea reflection and evaluation*, in order to rise above tensions from conflicting perspectives to achieve a deeper understanding of what is read. Fig. 1 shows the socio-cognitive dynamics of idea-centered discussions where students are *working with ideas* in design mode: As ideas are diversified, the quantity of ideas increases, and as ideas are elaborated, the quality of ideas increases. Both processes are necessary for idea improvement (Hong & Sullivan, 2009). While sometimes, the teacher may intervene with a bit of direct instruction, overall the teacher supports the community to self-organize around the KB principles in ways that continually improve ideas and advance collective understanding.

The socio-cognitive dynamics of Knowledge Building are further supported in an online networked environment for collaborative discourse and sustained idea improvement, called Knowledge Forum (Zhang, Hong, Scardamalia, Teo, & Morley, 2011). Knowledge Forum (KF), is developed to integrate technology and pedagogy to improve students' reading and writing skills in a Knowledge Building community (Scardamalia & Bereiter, 1991; 2010). In this online community space, students contribute their ideas and questions and then try to connect their ideas with their peers' ideas via build-on notes in order to expand their comprehension surrounding the text they read. Specifically, the note editor has keyword and problem tags to identify shared problems of understanding, as well as a set of supportive scaffolds to help students compose ideas, critique ideas, and improve ideas (e.g., My theory, This theory doesn't explain, Putting our knowledge together). Community knowledge emerges in KF when students take on high levels of agency for designing conceptual spaces for addressing shared problems/questions, exchanging and interacting with conceptual resources, and building on one another's ideas to reach deeper levels of understanding (Bereiter, 2002).

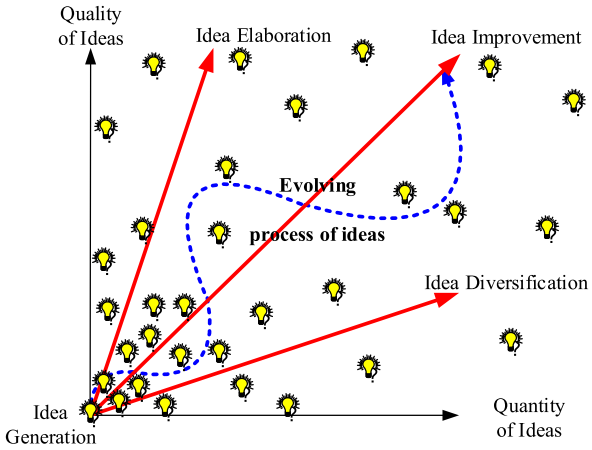

Fig. 1. Idea-centered discussion in a reading community. Source: adapted from (Hong & Sullivan, 2009).

2.3. This study

In an extensive review of Knowledge Building (KB) research in the past 30 years (Chen & Hong, 2016), there have been only limited empirical studies conducted within non-Asian learning contexts that were broadly related to reading literacy (e.g., see Pelletier, Reeve, & Halewood, 2006; Sun, Zhang, & Scardamalia, 2008; Sun, Zhang, & Scardamalia, 2010a, 2010b; Zhang & Sun, 2011). These studies indicate that elementary school students' reading, writing, and related activities on KF are positively related with vocabulary growth (Chen, Ma, Matsuzawa, & Scardamalia, 2015; Sun et al., 2010a, 2010b), reading skills (Zhang & Sun, 2011) and essay writing (Lin, Hong, & Ma, 2019). When it comes to developing higher-level reading comprehension skills, it remains to be explored whether young students, particularly third-grade students, would benefit more from direct instruction or sustained Knowledge Building discussions supported by KF technology. The current study thus investigates how adopting a principle-based approach over a direct instruction approach can support the development of young students' literacy in a Chinese reading class. More specifically, we explore how students' reading skills, particularly their higher-level reading comprehension skills, can be improved through collaborative reading activities supported by Knowledge Building pedagogy and Knowledge Forum technology. The research questions are:

1) How did students' reading comprehension scores on the PIRLS test compare in the Knowledge Building class versus the direct instruction class?
2) How did the use of KF support the development of students' reading comprehension? What are the relations, if any, between students' online collaborative activities and reading comprehension scores?
3) How did the quality of discussions on KF (i.e., questions and explanations) evolve over time?

3. Method

3.1. Participants, contexts, and class activities

The participants were two third grade classes from an elementary school located in a low socioeconomic neighborhood in Taipei, Taiwan. Students were randomly assigned to the experimental class which engaged in Knowledge Building (n = 24) or the comparison class which engaged in direct instruction (n = 27). The teacher in the experimental class had five years of teaching experience, two of which focused on innovating practices with KB pedagogy and KF technology. The teacher in the comparison class, on the other hand, had more than ten years of experience teaching reading using traditional methods, such as direct instruction. As for the students, none of them had any experience with KB or KF prior to the study. The study took place over a semester of 14 weeks.

Within the current educational context in Taiwan, elementary school teachers are required by the national curriculum guideline to use pre-designated textbooks for their Chinese language arts teaching (Taiwan Ministry of Education, 2019). As such, both the experimental and comparison classes were to read the same content from a scientific textbook about animals, plants, and biodiversity in ecosystems, including "Taiwan Salamander: Hynobius Formosanus," "Hakka Tung Blossom Festival," and "Nature's Museum." For each article, the instructional process was divided into two parts. In the first part, direct instruction was employed in both classes as follows: (1) introducing new vocabulary of the article; (2) introducing and discussing key phrases and sentences in the article; (3) summarizing and discussing the outline of the article; (4) explaining and discussing each paragraph of the article; (5) assessing

Fig. 2. A sample KF view and note featuring various tools to help students produce and work with ideas. Note: KF tools guide students to mark discussed problems and identify keywords and use scaffolds to work creatively with their ideas.

students' understanding by asking questions during and after the lecture. It is important to note that helping students develop higher-level reading comprehension skills has always been a top goal required in the national curriculum guideline (Taiwan Ministry of Education, 2019). So, in the second part, students in the comparison class (direct instruction) were guided by the teacher to complete independent work, such as practice worksheets administered at the end of the lesson, that requires higher-level skills such as interpreting, integrating, examining, and evaluating content. In contrast, students in the experimental class (Knowledge Building), came together as a reading community and worked collaboratively in Knowledge Forum to engage in the following principle-based, idea-centered activities (in no particular order and as often as needed): (1) Real ideas and authentic problems—students summarized their understanding from reading the article, identified keywords and problems that they really cared about, and searched online for information to propose initial ideas to tackle problems they decided were worthy of further investigation in Knowledge Forum (see Fig. 2 for examples); (2) Idea diversity—students gathered information from the Internet, exchanged ideas to seek convergence across ideas expressed in the textbook and by their peers in Knowledge Forum, and challenged each other's thinking by examining ideas from different viewpoints; (3) Idea elaboration—students asked one another questions to probe for clarification or elaboration of previous ideas posted; and (4) Idea integration and improvement—students integrated various ideas in order to improve the initial ideas and then synthesized them into more advanced and coherent explanations that accounted for diverse viewpoints. Each of these online activities occurred in KF in which students use various tools, such as problem-identification, keyword tagging, and scaffold marker as guidance to frame their contributions and sustain the process of idea improvement (Scardamalia, 2004). Fig. 2 illustrates various idea-centered activities online in which students engaged with multiple sources of ideas and texts in the KF multimedia platform—a doorway for students to connect what they learned from textbooks and real-world problems.

3.2. Data source and analysis

This study used PIRLS released reading passages and items as pre- and post-assessments. Data were collected from both classes and Knowledge Forum data from the experimental class was collected to assess the quality of students' discussion and reading comprehension. First, the participants from both the experimental/comparison classes took pre- and post-assessments before and after the 14-week intervention to examine changes in reading comprehension. PIRLS defines four levels of reading comprehension skills: *(1) retrieving explicitly stated information* and *(2) making straightforward inferences* on the two lower-levels, and *(3) interpreting and integrating ideas and information* and *(4) examining and evaluating contents, languages and textual elements* on the other two higher-levels (Mullis et al., 2017) (see columns 1 and 2 in Table 1).

The reading assessment used in this study included two articles: one for literary experience and the other for applying new information. The contents of the two articles were based on four different comprehension processes that readers use to interpret and understand both literary and informational texts. The official PIRLS scoring guidelines were used to evaluate students' reading comprehension. Students got one point for each correct response on a multiple-choice question, and they received a score from one to three points on the constructed-response questions, depending on the depth of understanding. The constructed-responses were used to assess whether students engaged in lower- or higher-level comprehension processes. Two teachers graded students' answers consistent with the PIRLS definition of literacy underlying the interaction between the reader, context, and task. The inter-coder reliability was 0.91 ($p < .001$). A one-way ANCOVA on the total PIRLS score was performed to determine whether any differences existed between the two classes.

Second, for the experimental class, students' online reading and collaboration activities were automatically logged in a KF database. This data included: number of notes contributed, number of notes read, and number of notes built-on. To explore changes in students' online activities, the semester was divided into two phases, with the mid-term serving as a separation point for comparison. T-tests were employed to examine how students engaged in online activities in KF from the first phase to the second phase. In addition, we also explored whether there were associations between students' online activity performance and improvement in their PIRLS reading comprehension scores. Regarding students' online activity performance, the five dimensions of online activities (i.e., # of notes contributed, # of notes built-on, # of notes read, # of keywords, and # of scaffolds) were transformed into standardized z-scores and then the average of the five z-scores were used as a cut-off score to categorize students into high-performing and low-performing groups. As for the improvement in students' PIRLS reading comprehension scores, because the official PIRLS scoring guidelines were used to evaluate students' reading comprehension, we also used the average score, derived from the difference between the pre-post

Table 1
Coding scheme based on PIRLS reading comprehension levels and example of student writing.

General level	Specific level	Example
Lower-levels (Retrieving and Straightforward Inferencing)	Level 1: Retrieving explicitly stated information	"The Taiwan salamander is a species protected under the category of 'critically-endangered' and its mucus coating on damp skin is toxic." (s21)
	Level 2: Making straightforward inferences	"The poisonous skin coating can protect them from being attacked by its predators." (s13)
Higher-levels (Interpreting, Integrating, and Evaluating)	Level 3: Interpreting and integrating ideas and information	"Taiwan salamanders have survived from the Ice Age, so as long as we can love and protect our mother earth from global warming, Taiwan salamanders will not become an "extinct" species." (S18)
	Level 4: Examining and evaluating contents, languages and textual elements	"Taiwan salamander usually nested on the shore of a mountain creek and prey on frags and fishes. Their spawning season is around August. They lay eggs under the sand and let eggs hatch by themselves." (S2)

PIRLS assessment scores, as a cut-off score to categorize students into high-score and low-score groups. Then, Chi-square was performed to see if there were associations between students' online activity performance and improvement in their PIRLS reading comprehension scores.

Third, the content of students' actual online discussion was also analyzed. Using the note as the unit of analysis, all notes were examined and put into two general categories: question notes and explanation notes. The former category included questions about the content of the articles read and questions relating the article contents to one's life experiences, and the latter category included mainly ideas produced, exchanged, and discussed to answer and/or explain those questions. To further examine the quality of notes, we also qualitatively categorized these "questions" and "explanations" into the four different levels of comprehension skills as defined by PIRLS. Using randomly selected 50% of notes, two researchers coded participants' note content and assigned each note to a level of reading comprehension, with differences resolved by discussion. Using Spearman's ρ, the inter-coder reliability was 0.83 ($p < .001$). In addition, we traced how the focus of the online discussion shifted from lower to higher levels of comprehension by highlighting examples of questions and explanations students wrote in KF.

4. Results and discussions

4.1. Students' reading comprehension scores before and after the intervention

To address RQ1 regarding students' reading comprehension, first, an overall one-way ANCOVA analysis on the total PIRLS score was performed to see if there were any differences between the two classes. The hypothesis of homogeneity of regression slopes was first tested and no violation of this hypothesis was found ($F = 2.84$, $p > .05$). Then, as Table 2 shows, the ANCOVA test found that the increased total score from the pre-test ($M = 16.29$, $SD = 6.50$) to the post-test ($M = 25.79$, $SD = 6.67$) in the experimental class is significantly higher than the improved score from the pre-test ($M = 20.89$, $SD = 4.15$) to the post-test ($M = 24.81$, $SD = 4.18$) in the comparison group ($F = 28.52^{***}$, $\omega^2 = 0.37$). This indicates that while controlling for the pre-test, students in the KB class outperformed the students in the direct instruction class on the PIRLS reading test.

The next step was to examine the differences between the two classes in terms of the four specific levels of reading comprehension. To this end, we conducted a one-way ANCOVA and before doing so, again, a test if the regression coefficients in the group satisfy the hypothesis of homogeneity. The result also showed no violation of such statistical assumption ($F = 3.87$, $p > .05$; $F = 4.00$, $p > .05$; $F = 0.40$, $p > .05$; $F = 0.08$, $p > .05$, from level 1 to 4 respectively). Then, the following ANCOVA tests showed that there is no significant difference between the two groups in level 1 ($F = 1.03$, $p > .05$) and level 2 ($F = 1.38$, $p > .05$), but there is a significant difference in level 3 ($F = 19.47$, $p < .001$) and level 4 ($F = 5.18$, $p < .05$). These results indicate that the KB intervention is at least as good as the direct instruction intervention in developing students' lower-level reading skills (e.g., retrieving explicitly started information, making direct inferences); but, more importantly, it was found that the KB intervention was more likely than the direct instruction intervention to help students in improving their higher-level reading comprehension skills (e.g. interpreting/integrating ideas, examining/evaluating information). As students' online activities were guided by the four KB principles – Real Ideas and Authentic problems, Idea Diversity, Improvable Ideas, and Rise Above – naturally, their work in Knowledge Forum provided sustained opportunities for them to engage in critical and reflective thinking as to how to work progressively with ideas in order to make the wealth of information and explanations in the community more clear and coherent to their peers. They also engaged in higher-level processes in KF by identifying problems of understanding, tagging keywords to notes, and using scaffolds to support discourse aimed at idea improvement. Accordingly, these activities may have contributed to students' improvement in higher-level reading comprehension.

4.2. Students' online reading and discussing activities in relation to their reading comprehension scores

Regarding RQ2, we posited that engaging students in principle-based, idea-centered activities online is conducive to improving their reading comprehension. To examine if students successfully worked together as a Knowledge Building community, we analyzed

Table 2
Average scores of experimental and control groups' reading comprehension skills.

Reading comprehension processes		Experimental	Control	F-value	ω^2
		M(SD)	M(SD)		
Total score of level 1 to 4 combined	Pre-test	16.29(6.50)	20.89(4.15)	28.52***	0.37
	Post-test	25.79(6.67)	24.81(4.18)		
Specific level					
Level 1: Retrieving explicitly stated information (8Qs)	Pre-test	5.71(2.31)	7.00 (1.54)	1.03	0.02
	Post-test	7.38(2.18)	7.93(1.36)		
Level 2: Making straightforward inferences (8Qs)	Pre-test	4.17(2.10)	5.30(1.68)	1.38	0.03
	Post-test	6.25(2.35)	6.37(2.15)		
Level 3: Interpreting and integrating ideas and information (10Qs)	Pre-test	6.00(2.62)	7.74(2.38)	19.47***	0.29
	Post-test	10.00(2.32)	8.81(1.75)		
Level 4: Examining & evaluating content, language & textual elements (2Qs)	Pre-test	0.42(0.88)	0.85(0.82)	5.18*	0.1
	Post-test	2.17(0.82)	1.70(0.87)		

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

their online activities. As shown in Table 3, the amount of online activities increased across the semester, with students being more active in the second phase than the first phase. The main online activities included the number of notes contributed ($t = -5.35$, $p < .001$), the number of notes read ($t = -4.15$, $p < .001$), the number of keywords used ($t = -3.49$, $p < .001$) and the number of scaffolds used ($t = -5.21$, $p < .001$). The results indicate that students became more engaged, through continuous reading and writing, in their online knowledge work over time and were taking ownership of their online reading community by identifying and discussing key ideas in the text and discussion. However, the increase in the number of notes built-on was not significantly different ($t = -.34$, $p > .05$) throughout the semester. This could be due to students spending more time at the latter second phase in improving the quality of their ideas and content of their discussion (see below 4.3 to find more descriptive analysis of the online discussion content).

As another piece of evidence regarding community building, as Table 3 shows, except for students' note-reading activities, the more active students were in one particular online activity (e.g., contributing, building-on, keywording, and scaffolding), the more likely they would also engage in another community activity. Furthermore, we examined the association between students' online activity performance and their improved PIRLS test scores. As Table 4 shows, a Chi-square test shows that there is an association between these two main constructs, namely students who were actively engaged in interactive, online collaboration activities showed improvement on PIRLS reading test scores.

4.3. Students' online discussion in Knowledge Forum and how their questions and explanations evolved

Regarding RQ3, the evolving process of students' online discussion, Fig. 3 shows how the focus of students' online discussion changed from the first and the second phase in terms of the levels of reading comprehension. In the first phase, there was a relatively higher percentage of questions and explanations found in lower-level reading comprehension (35% of level 1 and 28% of level 2 for questioning; 35% of level 1 and 31% of level 2 for explaining). In contrast, in the second phase, there was a relatively higher percentage of questions and explanations found in higher-level reading comprehension (35% of level 3 and 31% of level 4 for questioning; 35% of level 3 and 32% of level 4 for explaining).

In further examining the quality of students' online discourse through content analysis, we found that the focus of students' online discussion shifted from superficial to deeper levels of reading comprehension. In the first phase, the student discussion was more focused on lower-level reading comprehension questions, which required only retrieving explicitly stated information or facts (level 1). For instance, after reading the unit of "The Taiwan salamander: Hynobius formosanus," a student posted a note inquiring, "What are some characteristics of hynobius formosanus" (by s1)? In response to this question, students were able to share simple facts such as "The back of Taiwan salamander has some white spots" (s15) and "The Taiwan salamander is a species protected under the category of 'critically-endangered' and its mucus coating on damp skin is toxic" (s21). The question and responses by these students seem to be more concerned with simple facts relevant to what they read from the textbook and the Internet. At this stage, the discussion was also more focused on making straightforward inferences (level 2). For example, building on the above discussion thread, the same student S1 further asked, "Why is the Taiwan salamander a protected, 'critically-endangered' species? Why is its mucus coating on damp skin toxic? Is there a useful function"? As there is no explicitly stated information that can be found in the textbook, students needed to infer from what they read in the text. For example, by putting together scattered pieces of information, students made inferences such as "Taiwan salamander is a protected species because its total number is very limited, is extremely scarce" (s13) and "The poisonous skin coating can protect them from being attacked by its predators" (s13).

In contrast, it was found that in the second activity phase, students' online discussion became more concerned with higher-level reading comprehension. For example, in terms of interpreting and integrating ideas information (Level 3), when a student asked in KF, "What do you think? Will Taiwan salamanders become extinct?" (S17), several students responded by interpreting what they read in the text and even suggested ideas to protect Taiwan salamanders' habitat such as "Because people are protecting Taiwan salamander's habitat now, they will not become extinct." (S18). "They will not go extinct as long as we love and preserve their natural habitat" (S23). "Nope! Because they are protected under the 'critically-endangered' species policy" (S11). "Taiwan salamanders have survived from the Ice Age, so as long as we can love and protect our mother earth from global warming, Taiwan salamanders will not become an extinct species" (S18). "The key to protecting Taiwan salamanders' habitat is not to drop trash with abandon. So they can grow up happily and safely in Taiwan." (S22). Further, in terms of Level 4 reading comprehension, there were also some discussions showing students examining, evaluating, and reflecting on the text for deeper understanding. For instance, in one conversation about extinction, a student said, "Taiwan salamander is usually nested on the shore of a mountain creek and prey on frags and fishes. Their spawning season is around August. They lay eggs under the sand and let eggs hatch by themselves" (S2). In this case, based on the

Table 3
Description of students' online activities in Knowledge Forum (n = 24).

KF activities	First phase		Second phase		t-value	2	3	4	5
	M	SD	M	SD					
1. # of notes contributed	12.42	3.63	16.42	3.91	−5.35***	0.93***	0.31	0.87***	0.91***
2. # of notes built-on	8.29	3.46	8.5	2.62	−0.34	1	0.43**	0.82***	0.85***
3. # of notes read	92.63	46.22	161.2	106.8	−4.15***	–	1	0.44**	0.21
4. # of keywords	9.17	4.03	11.67	3.74	−3.49**	–	–	1	0.83***
5. # of scaffolds	11.25	4.33	15.75	4.1	−5.21***	–	–	–	1

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

Table 4
Association between the performance of students' online activities and their improved reading assessment score.

Reading assessment score	Performance of online KF activities	
	Low-performing group	High-performing group
Low-score group	8	2
High-score group	5	9
Chi-Square	4.61*	

Note: *$p < .05$; number in the table shows the number of students in each category.

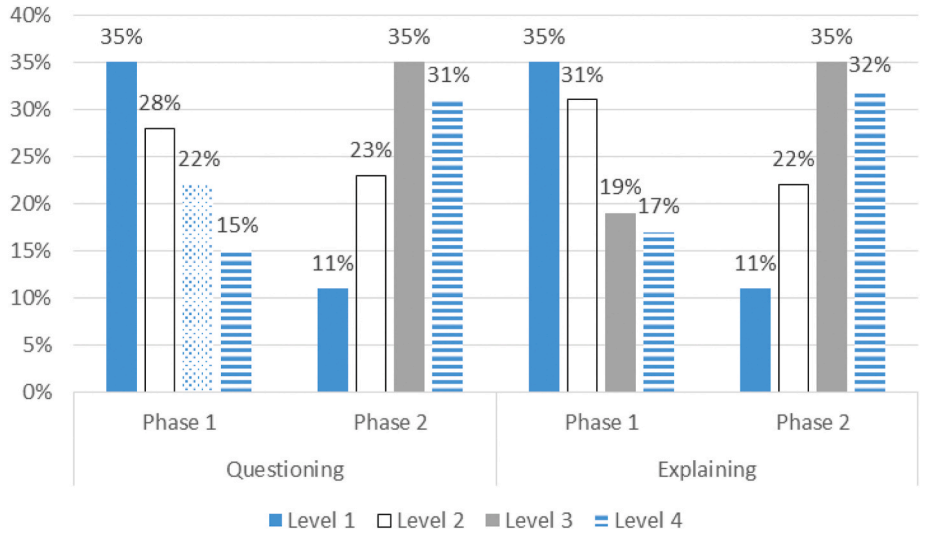

Fig. 3. Focus of students' online discussing, questioning, and explaining behaviors in terms of the levels of reading comprehension from first to the second KB phase.

content evaluation, S2 was able to introduce some new ideas that she learned from the Internet regarding how Taiwan salamanders protect their eggs to avoid becoming extinct. Later on, the students' discussion further centered on the issues of population decline and species in Taiwan. For example, a student said,

> Taiwan salamanders are not afraid of cold weather as they live in the high mountain and they are nocturnal. As their habitat becomes smaller and smaller, we should protect their habitat. I will be sad if they go extinct as there will be one less species in Taiwan. Due to global warming, they deserve more protection. *(S24)*

In this case, s24 reflected on relations between global warming, habitats, and the responsibilities they have to protect endangered species. It can be seen that, over the semester, students' discussion moved from retrieving information or facts, and making inferences (Levels 1&2) to interpreting information and integrating and evaluating information with their ideas (Levels 3&4). Students demonstrated an enhanced ability to make connections between information from their textbook and authentic environmental issues, and to integrate each other's ideas and information from their textbook and the Internet into new ideas to address real-world problems.

5. Conclusion and implications

This study explores traditional and innovative designs for teaching reading to young students in a Chinese literacy class over the course of a semester. First, we assessed an experimental and comparison class' reading comprehension and found that students experienced more benefits in the innovative context, which involved Knowledge Building pedagogy and Knowledge Forum technology, rather than the traditional context, which involved direct instruction and worksheets. More specifically, student-directed discussions in the computer-supported collaborative environment was more effective than a teacher-directed approach to improving higher-level reading comprehension as indicated by PIRLS scores. Second, positive relationships between online activities and improved PIRLS scores support the notion that students were able to work together as an online reading community in KF – their questions and build-on ideas deepened their understanding of the articles they read. Moreover, the significant increase of KF activities over time also indicates a growing interest in collaboration over individual learning. Third, the qualitative examination of students' online discussion in KF also showed that while in the initial phase, students tended to focus more on the basic levels of reading comprehension (e.g., retrieving facts), over time, they shifted towards higher-level reading comprehension skills (e.g., interpreting and integrating ideas) to sustain discussions. Taken together, these findings suggest that Knowledge Building pedagogy supported by Knowledge Forum technology can enhance third graders' reading comprehension in a Chinese literacy class in Taiwan.

Several implications can be made from this study. First, it is possible to engage young kids in independent, self-initiated reading activities with the use of appropriately designed interactive technology (Delen & Liew, 2016). Our study shows that under a principle-based, idea-centered pedagogy, even children as young as 8–9 years of age are able to engage in collaborative online discussions and to work productively with ideas in Knowledge Forum—i.e., generating, sharing, explaining, and building on ideas in order to address shared questions of interest derived from their textbook reading. Second, reading is predominantly regarded as an individual activity. More recent studies like this one, however, are arguing for the importance of forming reading communities for developing productive reading strategies and engaging students as readers for life (Cremin, Mottram, Collins, Powell, & Safford, 2014; Kusanagi, Kobayashi, & Fukaya, 2018). Our study adds that KB pedagogy, supported by KF technology is one effective method for fostering a reading community, and offers social and cognitive benefits beyond direct instruction approaches. Thirdly, it is also important for the teacher to create a classroom culture that fosters reading for Knowledge Building (Yang, van Aalst, Chan, & Tian, 2016) so that students can feel comfortable reading collaboratively, sharing their initial ideas, and interacting publicly with each other's ideas to deepen individual and collective understanding (Hong & Sullivan, 2009).

Teaching has long been regarded as a highly prestigious and well-respected job in Chinese societies wherein teachers are professionally trained to effectively deliver expert knowledge to students. Direct instruction, therefore, remains a useful approach to teach reading in certain contexts (Stockard et al., 2018). As our societies enter the fourth industrial revolution, however, direct instruction alone will not sufficiently prepare students to be competitive and active citizens in the digital age. Teachers, therefore, do need to take into serious consideration effective ways of leveraging digital technologies to teach reading for advancing students' reading competencies (Coiro et al., 2014; Goldman & Scardamalia, 2013). Digital technologies and artificial intelligence are changing the nature of reading and redefining what it means to be literate in an open information world, offering new opportunities and challenges for students to engage with complex representations of information online. Tensions arise within the context of many East Asian countries similar to Taiwan, however, where the national curriculum guideline requires the use of pre-determined textbooks for teaching language arts and other core subjects. While the Knowledge Building intervention still involved use of an authoritative text given by the teacher, students were given the opportunity to read multiple interpretations and critiques of the same text, which is not common in a typical primary classroom. Furthermore, students had the opportunity to seek out additional authoritative resources and texts on the Internet to support their online discussion, which enriched their learning. Therefore, it can be said that when compared with direct instruction, Knowledge Building pedagogy enabled students to have more autonomy and ownership in their online learning, reading, and discussion. This is important as some experts consider self-initiated learning to be a key digital competency in networked societies (Levinsen, 2011). It is even possible to integrate reading instruction with other 21st century competencies, such as collaboration, communication, and community-building skills (Ma, Matsuzawa, & Scardamalia, 2016).

Within the current reform context in Taiwan, teachers are being challenged to implement more effective practices that integrate innovative pedagogies and technologies for teaching reading and new literacies. Our findings suggest that there are three unique values of adopting a Knowledge Building pedagogy in a reading class. First, it can complement the traditional method of direct instruction by guiding students to engage in reading not merely for acquiring textbook knowledge, but also for advancing knowledge that is more meaningfully related to their lived experiences in their local context. Second, Knowledge Building pedagogy not only helps deepen young readers' content knowledge but even more importantly empowers them to progressively take ownership of higher-level reading comprehension processes. Third, unlike direct instruction that highlights individual learning and reading tasks, engaging students in Knowledge Building in computer-supported collaborative learning environments also offers great potential for supporting the emergence of new literacies (e.g., technology literacy) and 21st century competencies (e.g., working creatively with ideas and collaborating with peers) that are required in networked societies. Nevertheless, more complex and dynamic assessments will need to be designed in parallel with the design of learning environments to trace the developmental trajectory of these competencies. Future work should aim to extend our designs over different cultural contexts to further explore the evolution of students' ideas as well as collective knowledge processes that facilitate the development of reading and writing skills during Knowledge Building.

CRediT authorship contribution statement

Huang-Yao Hong: Conceptualization, Methodology, Investigation, Writing - original draft, Supervision, Resources, Funding acquisition. **Leanne Ma:** Conceptualization, Writing - review & editing. **Pei-Yi Lin:** Methodology, Formal analysis. **Karen Yuan-Hsuan Lee:** Validation, Funding acquisition.

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