

# Self-directed reflective assessment for collective empowerment among pre-service teachers

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## Abstract

This study investigated the role and process of self-directed reflective assessment (SDRA) enhanced by learning analytics to support pre-service teachers' (PTs') collective empowerment in a knowledge-building (KB) classroom. The participants were 43 second-year PTs from a compulsory course taught by a teacher who had 2 years' teaching experience. A comparison class of 47 PTs, taught by the same teacher and studying the same topics in a regular KB environment, also participated. Statistical analysis revealed significant differences in participation and domain understanding between the experimental class and the comparison class. Qualitative tracing of the SDRA group's online discourse indicated that the PTs were empowered and that their collective empowerment increased gradually over time. Analysis of the PTs' prompt sheets revealed that analytic-supported SDRA helped the PTs engage in collective decision making to choose and judge promising ideas, and in collective synthesis and "rise-above" of ideas, thus helping them engage in high-level collective empowerment. The findings have important implications for the design of technology-rich environments as metacognitive tools to support learners' empowerment, and they shed light on how teachers can use such tools to engage learners in metacognitive practices to increase their empowerment.

**Keywords:** Self-directed reflective assessment, empowerment, pre-service teachers, metacognition

## Introduction

Education should empower learners (Becker & Luthar, 2002; Snell & Lefstein, 2018). Helping learners to develop higher order competencies (eg, inquiry, metacognition, agency and collaborative knowledge creation) is critical for their empowerment (Bransford, Brown, & Cocking, 1999;

### Practitioner Notes

What is already known about this topic?

- Empowering pre-service teachers' (PTs') to master higher order competencies is particularly important; PTs' empowerment primarily consisted of these high-level competencies.
- Collaborative inquiry that can help learners to develop higher order competencies and further empowerment primarily depends on learners' metacognition.
- SDRA has great potential in empowering PTs, however, little research has been conducted to investigate the role and process of SDRA for supporting PTs.

What this paper adds

- SDRA can empower PTs and help them increase their empowerment over time.
- SDRA effectively drives PTs to actualize and develop their metacognition, which in turn fosters PTs to engage in collective decision making, idea negotiation, and idea synthesis and "rise-above" thinking, and thereby gradually helps the PTs increase their empowerment.
- The design of learning environments, which capitalizes on KB pedagogy and SDRA, is accessible to the PTs and fosters their collective empowerment.

Implications for practice and/or policy

- Establishing a democratic and collaborative learning environment, fostering a sense of community and confidence among learners, and helping learners to gradually develop necessary skills are important for supporting their empowerment.
- The learning design for empowering learners should support learners' agency, collective decision making, reflection and regulation, and collective KB.
- It is important to organize collective reflection opportunities to help students engaged in data-supported SDRA.

Snell & Lefstein, 2018; van Aalst & Chan, 2012), which primarily consists of such competencies (Hur, 2006; Salas-Pilco, 2017; Yang, van Aalst, & Chan, 2020). The development of these higher order competencies can not only help learners in their school work but also create the conditions for sustainable improvement (Becker & Luthar, 2002; Snell & Lefstein, 2018; Yang, van Aalst *et al.*, 2020). Empowering pre-service teachers (PTs) to master such competencies is particularly important; it can help them engage in productive learning and can also help them design the innovative teaching that is required in today's classrooms. Unfortunately, conventional teacher-training approaches tend to focus more on supporting PTs' accumulation and mastery of teaching knowledge and skills for direct instruction than on enhancing their development of higher order competencies (Chen, Chan, Chan, Clarke, & Resnick, 2020; Yang, Xu, Xu, & Luo, 2020). Here, engagement is defined as the effortful involvement in learning (Pekrun & Linnenbrink-Garcia, 2012), and emphasizes students' fundamental responsibility and contribution (D'Mello, Dieterle, & Duckworth, 2017).

Collaborative inquiry, a major research strand in education, can help develop learners' higher order competencies, and thus further empower them (van Aalst & Chan, 2012; Yang, Chen, *et al.*, 2020; Yang, van Aalst *et al.*, 2020). However, the progressive development of these competencies depends heavily on learners' ability to metacognitively reflect on and regulate their inquiry (Bransford *et al.*, 1999; White & Frederiksen, 1998, 2005; Yang, van Aalst *et al.*, 2020). This is problematic because many learners lack sufficient metacognitive awareness and metacognitive

skills for collaborative inquiry (White & Frederiksen, 1998; Yang, Chen, *et al.*, 2020; Yang, van Aalst *et al.*, 2020). Therefore, appropriate scaffolding is needed to help learners develop metacognitive awareness and skills and in turn increase their empowerment. Self-directed reflective assessment (SDRA) is one scaffolding strategy that has been shown to effectively support learners' metacognition and reflective inquiry (Lee, Chan, & van Aalst, 2006; Toth, Suthers, & Lesgold, 2002; van Aalst & Chan, 2007; White & Frederiksen, 1998; Yang, van Aalst *et al.*, 2020). SDRA refers to a type of assessment in which learners are given agency to use feedback to analyze tasks and identify knowledge gaps, plan and monitor their progress, and devise methods to improve their ongoing learning while addressing broader problems (White & Frederiksen, 1998; Yang, Chen, *et al.*, 2020; Yang, van Aalst *et al.*, 2020; Yang, van Aalst, Chan, & Tian, 2016).

In this study, SDRA activities were carried out in a knowledge-building (KB) classroom. KB is an influential educational and collaborative inquiry model in which students work as members of a community to improve both personal ideas and the community's collective knowledge (Scardmalia & Bereiter, 2014). This study aimed to examine whether PTs can use and benefit from an SDRA approach designed to increase their collective empowerment in a KB environment. In this study, we extended SDRA to collective dimensions in the KB environment. Not everyone needs to be highly metacognitive for SDRA to succeed, because students can support each other's progress. To support the PTs' SDRA, we provided them with the Promising Ideas Tool (PIT, Chen, 2017), a technique of learning analytics; we also emphasized students' self-directedness in using the process data from learning analytics to engage in collective reflection.

## Literature review

### *Empowerment*

The term "empowerment" was originally related to the idea of power in the physical sense; it was then used in relation to combating oppression and injustice in the 1970s and 1980s (Freire, 1972; Riger, 1993). Through the decades, the concept of empowerment has been used in the context of advocacies for increasing participation, strengthening capabilities, and encouraging agency and choice (Frymier, Shulman, & Houser, 1996; Hur, 2006; Wong, Zimmerman, & Parker, 2010). Nowadays, the term is defined in different ways. For example, Page and Czuba (1999) defined empowerment from a broad perspective, as a "social process that helps people gain control over their own lives" (para. 11). Byham (1992) conceptualized empowerment in education as a process in which learners take responsibility for their own progress by involving them in decision making. In this study, we adopted the definition proposed by Short and Greer (1993), who described empowerment as "the opportunities an individual has for autonomy, choice, responsibility and participation in decision making" (Short & Greer, 1993, p. 6).

Empowerment can be considered both a product and a process (Hur, 2006). As a product, empowerment is viewed as an expected long-term change in behavior, task accomplishment, and self-directedness (Hur, 2006). However, empowerment should not be seen as merely a fixed result or end-point (Starkey, 2003). As a process, empowerment is dynamic and constantly evolving over time; its nature is not linear but interactive and interrelated (Hur, 2006). Empowerment operates at both individual and collective levels, and individual and collective empowerment each have their own components (Hur, 2006). In this study, we focused on collective empowerment. Hur (2006) described collective empowerment as also having four components: (1) collective belonging, which, according to Boehm and Staples (2004), is "belonging to the social networks of their peers, and an emphasis on autonomy while being part of the collective and social solidarity vis-à-vis establishment" (Boehm & Staples, 2004, p. 274); (2) involvement in the community, or community engagement; (3) control over organization in the community, which refers to the capacity to influence the group; and (4) community building, which refers to the sense of

community, which increases the group's ability to work and solve problems together and make collective decisions. Collective empowerment aims to establish community building (Hur, 2006). Prior research has revealed that learning designs for empowering students are characterized by collaborative culture, quality activities, shared power and decision making, and mutual goal achievement (Kirk *et al.*, 2017; Salas-Pilco, 2017; van Aalst & Chan, 2012; Yang, van Aalst *et al.*, 2020). In the learning designs, students are valued as assets and epistemic agents; activities and participating structures are modified to encourage positive relationships and active participation; and cognitive social, and metacognitive responsibility as well as decision making are shared among all participating students (Salas-Pilco, 2017; Yang, van Aalst *et al.*, 2020). Some studies on elementary education have designed blended learning environments (Owston, 2018) or technology-supported environments (Salas-Pilco, 2017) to support students' empowerment. Unfortunately, relatively little research has focused on the design of learning environments and scaffolding strategies for empowering PTs (Yang, van Aalst *et al.*, 2020). There is a need to explore ways of designing socioculturally sensitive learning environments, activities and scaffolding strategies to support PTs' empowerment.

### *Promoting collective empowerment through a KB design augmented by SDRA*

#### Knowledge building

KB sees students' knowledge advancement as community-based, and aims to develop students' metacognitive and regulatory responsibilities, while actualizing teachers' directions into student initiatives for further student empowerment (Scardamalia & Bereiter, 2014; Yang, van Aalst *et al.*, 2020). In KB classrooms, students' inquiry is supported by Knowledge Forum® (KF), a computer-supported collaborative learning environment that facilitates collective idea advancement (see Figure 2). Using both online and offline discourse, the students work together to pursue inquiries and ideas, construct explanations, reflectively assess and direct further inquiry for deepening and rise-above in KB. Rise-above here refers to the extension of ideas to a higher level of conceptualization (Scardamalia & Bereiter, 2006, 2014).

KB includes many key learning sciences principles, including deep understanding, authentic learning, metacognition, scaffolding, the social process and technology-enhanced learning. It is aligned with research on the theories of "community of inquiry" (Akyol & Garrison, 2011; Garrison, Anderson, & Archer, 2010; Kilis & Yildirim, 2018), and "Fostering Communities of Learners" (Brown, 1997; Brown & Campione, 1994). KB is a principle-based approach that is driven by 12 interconnected principles (Scardamalia, 2002); among these, five principles are particularly conducive to increasing PTs' empowerment: (1) epistemic agency—students are guided to high-level knowledge work with related goals, long-range planning, and evaluations normally left to teachers; (2) democratizing of knowledge—everyone, regardless of accomplishment and background, can add value in a KB community; (3) community knowledge—knowledge advances cannot be made by individuals, and KB provides opportunities for PTs to advance together; (4) improvable ideas—all ideas are improvable, and their coherence, quality, and utility can be advanced by collective and continuous efforts; consequently, PTs are guided to make increasing collective efforts for continual idea improvement; and (5) reflective and transformative assessment—assessment is an integral component of KB that adds an inquiry component to the community's progress and work, and often leads to regulative actions such as planning, task analysis, reflection, and regulation and planning; these regulative actions are crucial for the success of PTs' KB inquiry and empowerment.

The implementation of KB in classroom settings has reportedly yielded positive results for empowering students (van Aalst & Chan, 2007; Yang, 2019; Yang, van Aalst *et al.*, 2020), although no specific research has focused on students' empowerment in KB contexts. KB involves students

working with multiple postings on KF; this process involves more than ideation in discourse and problem solving. The students are required to understand specific inquiries in the context of the community's other inquiries (past and current) and its effort to build a "big-picture" understanding of a domain. With ideas distributed across individual postings over time, students can easily get into fragmented or short discussions lacking in knowledge synthesis and conceptual progress (Yang *et al.*, 2016; Zhang *et al.*, 2018). Therefore, appropriate learning designs and scaffolding methods and tools should be provided to empower students to collectively engage in ongoing review and reflection on collective advances and gaps and regularly synthesize and transcend ideas in KB. Nevertheless, little research has focused on fostering the students' empowerment in KB.

#### SDRA enhanced by analytics

SDRA, which incorporates the metacognitive components of planning, monitoring and reflecting, drives students to deploy and develop their metacognitive awareness and skills, and directs them to improve their high-level competencies progressively and collaboratively. The engagement in the metacognitive process is critical for learners' empowerment. In KB contexts, the nature of SDRA is collaborative, it has three key aspects—concurrent, embedded, and transformative assessment. SDRA supports PTs' collective empowerment when it is ongoing and embedded in the regular curriculum; concurrent assessment is achieved when evidence-supported tools enable PTs to understand where they are now and where they are heading; and transformative assessment scaffolds students to reflect on their inquiry, and transform their KB processes.

Prior studies on SDRA in KB classrooms have revealed that students generally benefit from SDRA (Lee *et al.*, 2006; Lei & Chan, 2018; van Aalst & Chan, 2007). Previous research that we have conducted on SDRA enhanced by learning analytics in KB contexts suggested that students, even those who were low-achieving, could progressively increase their empowerment as reflected in improved academic performance and higher order competencies such as agency, knowledge creation and inquiry (Yang, 2019; Yang *et al.*, 2016; Yang, van Aalst *et al.*, 2020). In the present study, we also provided students with data from analytics to help them engage in SDRA in the inquiry process in the KB contexts, and thus helped them to gradually increase their collective empowerment.

#### *The present study*

Research on SDRA has revealed its great potential to foster collective empowerment among students (Yang, 2019; Yang *et al.*, 2016; Yang, van Aalst *et al.*, 2020). However, relatively few studies have investigated how SDRA can do the same for PTs. In this study, we designed an SDRA program for students using analytic tools in the KB context, specifically, the Promising Idea Tool (PIT) developed by Chen (2017). The PIT was originally designed as a separate learning-analytic tool but is now embedded in KF (see below). It can help students select promising ideas from those generated by their community, and supports the process of collective decision making in identifying promising directions for further inquiry (Chen, 2017). This study was part of a larger project that examined the design, process and dynamics of SDRA for supporting students' development of high-level competencies in collaborative inquiry. The study intended to characterize PTs' collective empowerment in collaborative inquiry in a KB classroom, and investigate the effects and process of SDRA in increasing PTs' collective empowerment. The following research questions were investigated.

1. Did the PTs in the KB environment augmented by PIT-aided SDRA participate more in Knowledge Forum and improve more in domain understanding than the PTs in a regular KB environment?
2. What characterized the PTs' collective empowerment in KB discourse, and to what extent could their collective empowerment be improved through SDRA?
3. How were the PTs empowered through SDRA using PIT?

## Methods

### *Research context and participants*

The study was conducted at a university in central China that trains teachers for K-12 education. One class of 43 PTs participated as the experimental class in this study, experiencing a KB environment augmented by PIT-aided SDR. Another class ( $n = 47$ ), the comparison class, engaged in a regular KB environment without PIT-aided SDR, which was also included to provide additional data. The two classes of PTs were enrolled in the same cohort majoring in Educational Technology, and were randomly assigned to the two classes when enrolling on a compulsory course (worth two credits and necessary for graduation) entitled Learning Sciences. The PTs in both classes reported similar pre-intervention academic achievement (based on school information) and gender composition, and studied the same inquiry topics in the Learning Sciences course for 18 weeks with two consecutive lessons (1.5 hours) each week. The primary objectives of the course were to help PTs understand theories of learning and to further develop their high-order skills (eg, inquiry, collaboration, metacognition, agency and knowledge creation) in the KB process. The course teacher had 2 years of prior experience using KB pedagogy to engage students.

### *Design of the KB environment augmented by SDR for empowering PTs (intervention)*

In the study, the experimental class experienced a learning environment that capitalized on KB pedagogy and technology; the environment focused on five intertwined KB principles: epistemic agency, democratic knowledge, community knowledge, idea improvement, and reflective and transformative assessment. The teacher used a three-phase pedagogical process with principle-based activities (see details in Figure S1 in the supplementary file) to support the PTs' empowerment: *Phase 1 (Weeks 1–5)—Creating a culture of democracy, inquiry, collaboration, and reflection for PTs' collective empowerment*; *Phase 2 (Weeks 3–9)—Initiating problem-centered inquiry and increasing PTs' collective empowerment through KF*; *Phase 3 (Weeks 10–18)—Supporting PTs' collective decision making and collective responsibility for deepening ideas by conducting PIT-aided SDR*. The design was adapted from our earlier studies by Yang (2019), Yang, van Aalst *et al.* (2020), and Yang, van Aalst *et al.* (2020) and refined for the PTs. Figure 1 detailed the phases of the pedagogical process, the sequenced activities in each phase, the purposes of the activities and the KB principles that were actualized by each activity.

At Week 10 in Phase 3, the teacher introduced the PIT (Figure 2) to the PTs for the PTs' SDR. The process of SDR using the PIT is depicted in Figure 3 that demonstrated how the teacher guided the PTs to understand and identify “promising ideas” and to the PIT, and how the PTs conducted SDR using the PIT and accompanying prompt sheets (see Table S1). At Week 14, the PTs were encouraged to conduct a second round of PIT-aided SDR on their KB inquiry from Week 10 to Week 13. Finally, the PTs were required to create an individual reflective-summary portfolio of notes in a different KF view, using KB principles (van Aalst & Chan, 2007; Yang, van Aalst *et al.*, 2020), between Week 17 and Week 18. In addition, the PTs were provided with weekly ATK data to promote their reflection on their participation and collaboration throughout Phase 3.

### *Instruction in the comparison class*

The PTs in the comparison class were involved in collaborative inquiry in the KB model and inquired into the same topics with facilitation from the same course teacher as that of the experimental class. In Phase 1 and 2, the comparison class and the experimental class conducted the same activities and tasks at the same pace. In Phase 3, the members of the comparison class were encouraged to enact high-level collective empowerment by creating reflective portfolio notes collectively using KB principles while the experimental class were guided to develop high-level

| Three-phased pedagogical process                                                                                                                                                                                                         | Activities designed                                                                                                                                                                                            | Purpose of the activities designed                                                                            | Knowledge building principles                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>Phase 1 (Weeks 1-5):</b><br>Creating a democratic and inquiry-based culture that empowered the PTs with voice, choice, and decision-making<br><br> | 1. Structuring a whole-class discussion by the teacher about refining and implementing an assessment rubric                                                                                                    | To create a culture of inquiry and democracy                                                                  | Epistemic agency; democratic knowledge                                                                                  |
|                                                                                                                                                                                                                                          | 2. Involving the PTs in setting the assessment criteria and deciding how they would be assessed                                                                                                                | To encourage the PTs' to take epistemic agency and to create a culture of democracy                           | Epistemic agency; democratic knowledge                                                                                  |
|                                                                                                                                                                                                                                          | 3. Encouraging the PTs to sign a learning contract                                                                                                                                                             | To facilitate the PTs' agency to self-direct their own learning                                               | Epistemic agency                                                                                                        |
|                                                                                                                                                                                                                                          | 4. Requiring the PTs (in student groups, 5-6 students) in making posters on how to be motivated and persistent in scientific inquiry and learning                                                              | To support the PTs' participation and collaboration                                                           | Epistemic agency; democratic knowledge                                                                                  |
|                                                                                                                                                                                                                                          | 5. Encouraging the PTs to write weekly reflections guided by prompts, such as "What have I and have I not learned about the theme?", and "What questions would I pursue for further inquiry about this theme?" | To help the PTs to develop reflection habits                                                                  | Epistemic agency                                                                                                        |
| <b>Phase 2 (Weeks 3-9):</b><br>Initiating problem-centered inquiry and increasing empowerment among the PTs in Knowledge Forum (Figure 2)<br><br>     | 6. Supporting the PTs in deepening inquiries in Knowledge Forum                                                                                                                                                | To support the PTs' development of competencies of inquiry, explanation and knowledge creation                | Epistemic agency; democratic knowledge; improvable ideas                                                                |
|                                                                                                                                                                                                                                          | 7. Face-to-face whole-class and small group discussion on contributing good discussion threads                                                                                                                 | To support the PTs' development of competencies of inquiry, explanation and knowledge creation                | Epistemic agency; improvable ideas                                                                                      |
|                                                                                                                                                                                                                                          | 8. Frequent collective reflections using the assessment rubric of productive discussion threads, examples from previous KB classes, and good notes written by the PTs                                          | To Support the PTs' development of knowledge creation abilities and metacognition                             | Epistemic agency; improvable ideas; reflective and transformative assessment                                            |
|                                                                                                                                                                                                                                          | 9. Frequent collective reflection supported by Knowledge Forum's integrated assessment tools                                                                                                                   | To support the PTs' development of metacognition                                                              | Epistemic agency; improvable ideas; democratic knowledge; reflective and transformative assessment                      |
|                                                                                                                                                                                                                                          | 10. The PTs in small groups conducted SDRAs using Promising Idea Tool                                                                                                                                          | To support PTs' collective decision-making, collective reflection, idea negotiation, synthesis and rise-above | Epistemic agency; community knowledge; democratic knowledge; improvable ideas; reflective and transformative assessment |
| <b>Phase 3 (Weeks 10-18):</b><br>Supporting the PTs' collective decision-making and collective responsibility for deepening ideas by conducting SDRAs.                                                                                   | 11. Encouraging the PTs to create portfolio-based summary notes using knowledge-building principles                                                                                                            | To support the PTs' decision making, reflection and idea synthesis                                            | Epistemic agency; improvable ideas; reflective and transformative assessment                                            |

Figure 1: Design of the KB environments augmented by SDRAs for empowering the PTs  
[Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

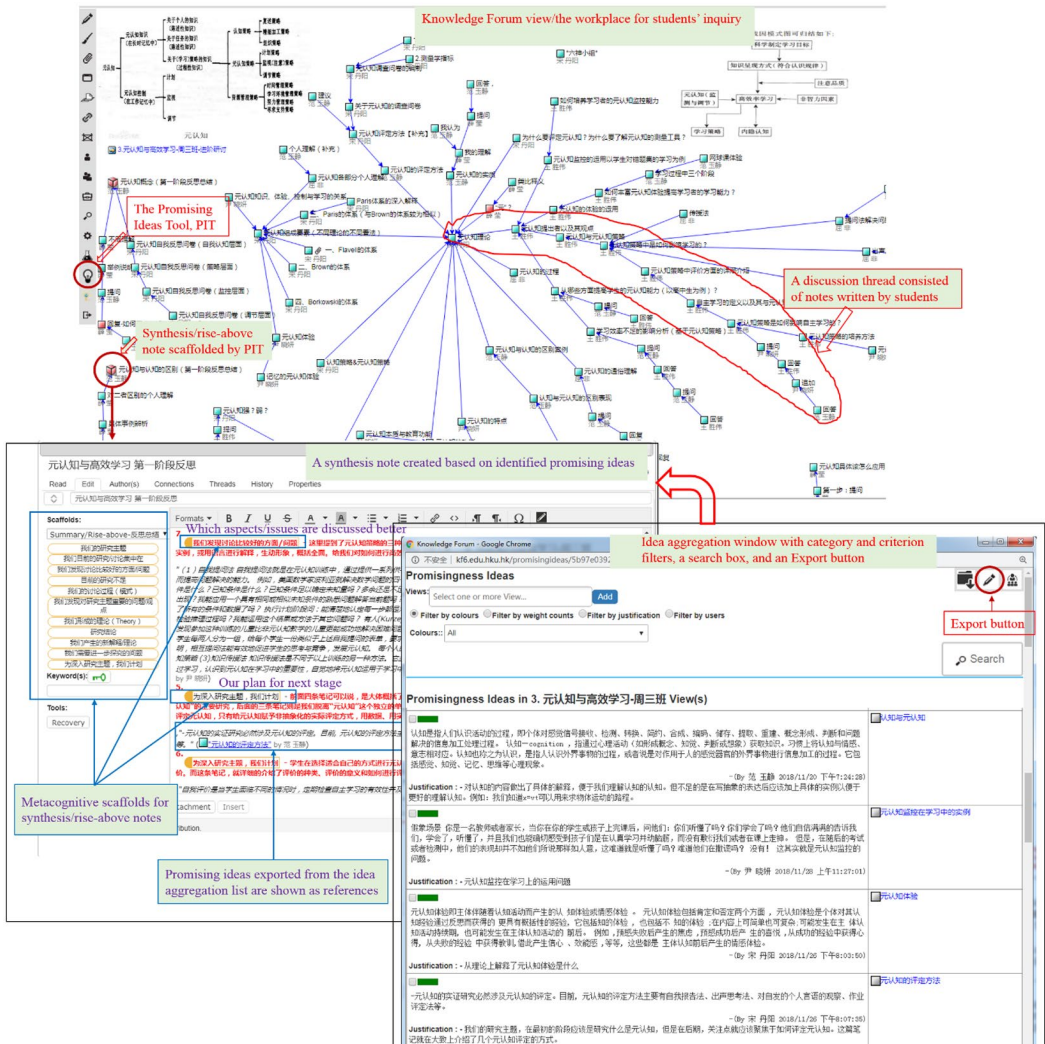


Figure 2: Screenshots from a view (top) and note (bottom left) in Knowledge Forum, and the Promising Ideas Tool (bottom right)  
[Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

collective empowerment through engagement in PIT-aided SDRA. Except for this, the two classes were involved in the same activities and tasks.

### Data sources and analysis

#### KF online notes

We used the KF notes contributed by the PTs to understand the characterization and development of the PTs' collective empowerment. We argued that the PTs' increasing collective empowerment was reflected by their increasing collective capability to advance their online inquiry discourse.

We first used the method of inquiry thread analysis to classify the KF notes into different inquiry threads to understand the collective, distributed and sustained nature of the PTs' inquiries.

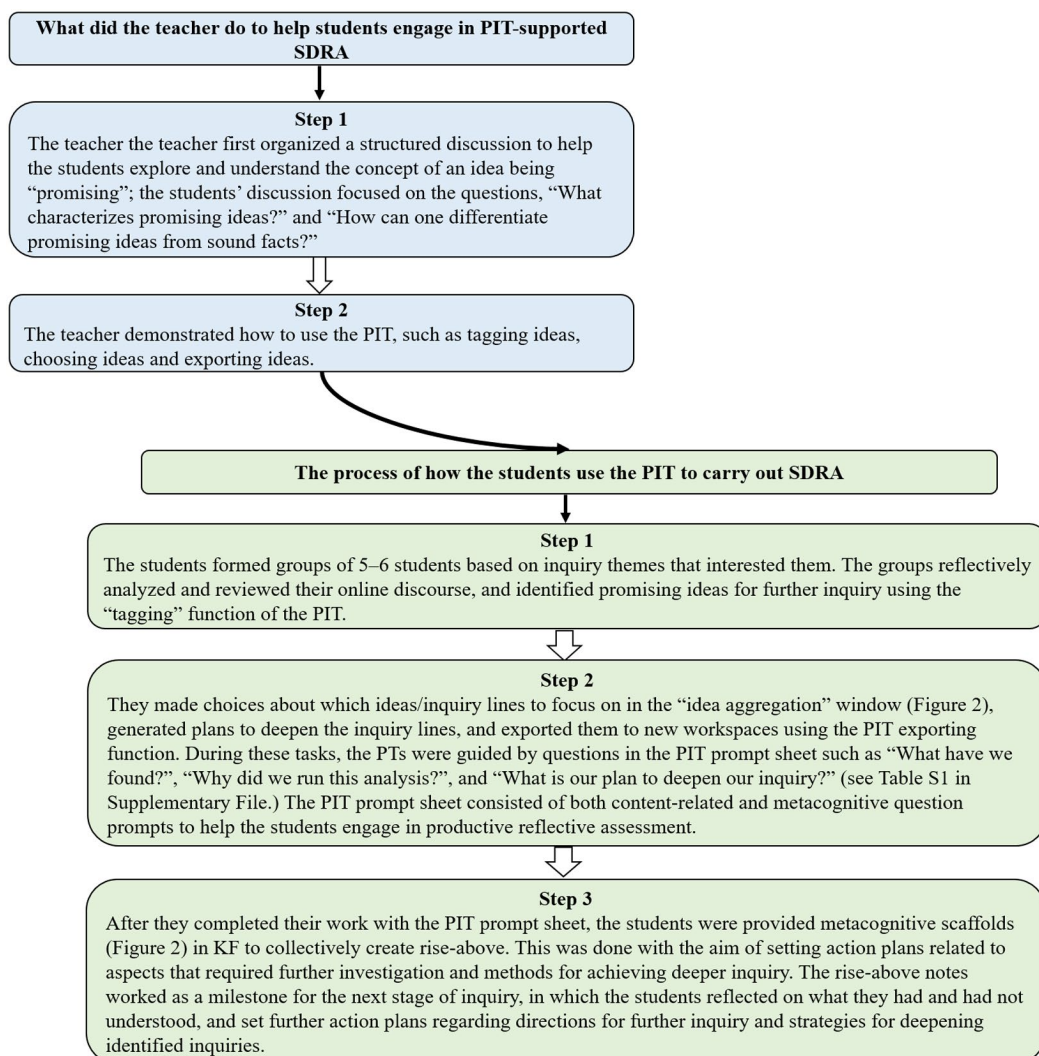


Figure 3: The process of SDR using the PIT  
[Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

The inquiry threads, as the unit of analysis, also provide the contexts for the subsequent content analysis in which we characterized the discourse within the inquiry threads. An inquiry thread consists of a sequence of notes for addressing the same principal problem; inquiry thread analysis is a method of reconstructing original clusters of notes into different inquiry threads (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). In conducting inquiry thread analysis, we first identified the principal problems by reading and re-reading all of the notes, followed by grouping the notes that focused on a common problem into one inquiry thread. In total, 1602 notes, excluding 43 individual portfolio-based reflective-summary notes from the experimental class, and 1434 notes, excluding 47 individual portfolio-based reflective-summary notes from the comparison class, were analyzed and assigned inquiry threads (Figure 4). Another colleague (She had obtained a PhD degree in Education, and was not one of the coauthors) in our research

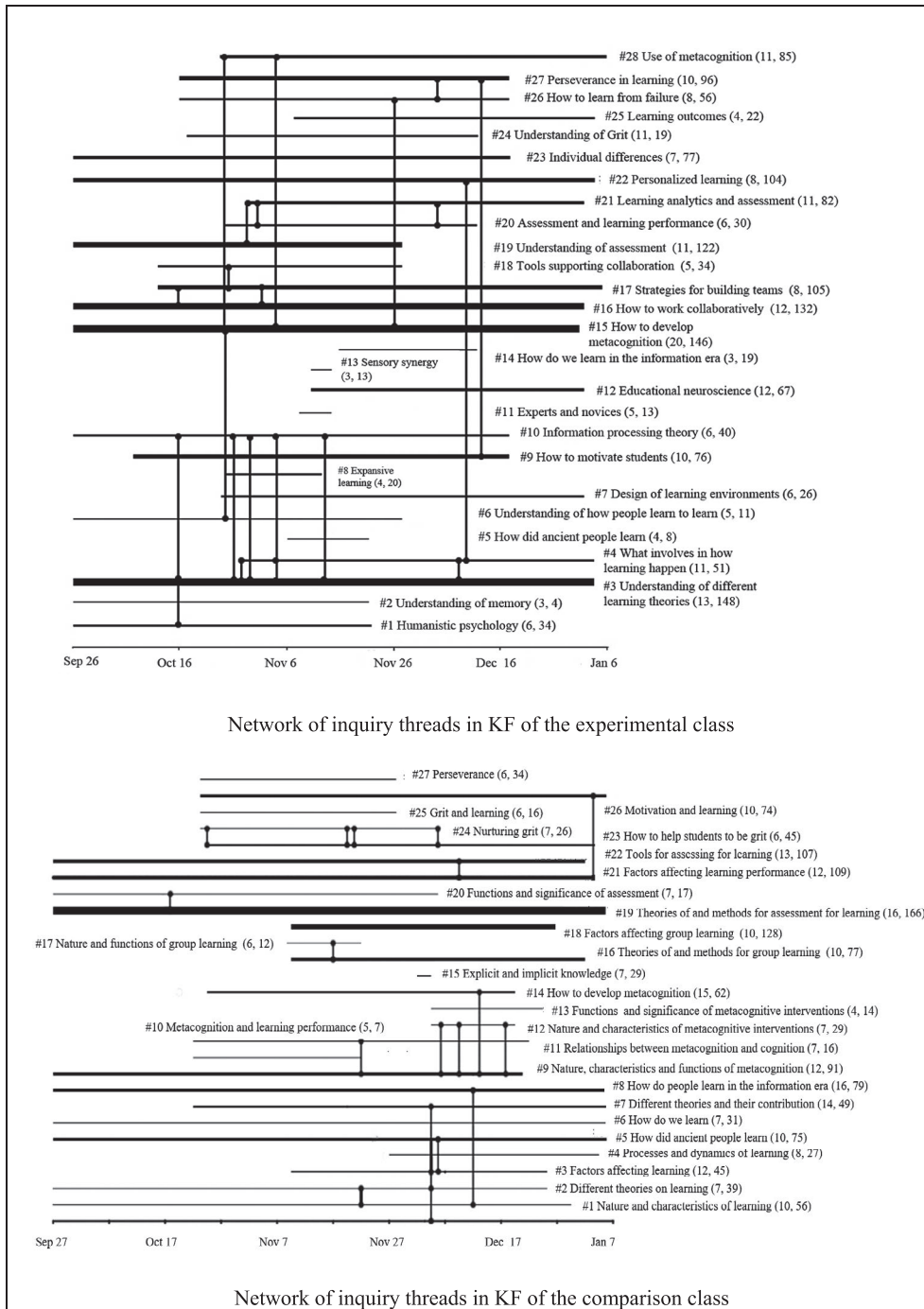


Figure 4: Network of inquiry threads in KF of the experimental and comparison classes. The number following the code indicates the number of authors and the number of notes, respectively. The dotted lines in identify bridging notes, which belong to more than one inquiry thread

group with experience in analyzing KF data independently assigned 30% of the notes to inquiry threads, and we achieved an inter-coder reliability of .83 (Cohen's kappa).

Next, we conducted content analysis of the students' notes within each inquiry thread using the coding framework adopted from Yang (2019). The framework was composed of different categories that reflected the PTs' collective empowerment; the categories included "question" (reflecting inquiry), "explanation" (reflecting ideation), "community" (reflecting collective knowledge creation and "metadiscourse" (reflecting metacognition). Two raters (the first author of this study and the above colleague) independently coded the notes from a sample of five inquiry threads ( $n = 500$ , 30%) and achieved an inter-rater consistency of 98% for question, 93% for ideas, 94% for community and 96% for metadiscourse.

### Domain understanding

To examine the PTs' knowledge gains on their inquiry topics, a test was administered at the end of the course. The test was designed by the course teacher, and the students were given 30 minutes to complete it. The test consisted of two open-ended questions: "What dimensions are involved in metacognition, how does it affect your learning, and how do you improve your own metacognition?" and "What types of assessment are used in our course and what are the features of each type of assessment, and how can they be used productively in our learning?" The students' responses were rated based on degrees of misunderstanding and whether a clear and coherent explanation was provided using a four-point scale from 1 to 4, with the details shown in Table S2. Two raters independently scored all of the data, and the inter-rater reliability was .84 (Cohen's kappa).

### Reflective prompt sheets for fostering empowerment

To illustrate the enactment process of empowerment through reflective assessment using the PIT, we collected the prompt sheets that had been designed to guide the PTs' productive reflective assessment. This approach was complemented through classroom observations, focus group interviews, and a combination of qualitative and quantitative analyses of data. The prompt sheet consisted of a set of both metacognitive and cognitive prompts (eg, "Our analysis," "Our problems" and "Our plan," and a set of specific question prompts). This was provided to the PTs to promote their collective decision making, as well as their reflection on and regulation of their on-line inquiry. The prompt sheets recorded the students' interpretations of the data, their analysis of their inquiry with the help of the data, and their action plans; they were distributed to student groups in class and were collected after class.

We first analyzed both productive and unproductive use of PIT data to identify the critical events of PIT-aided SDRA; these critical events fostered students' collective empowerment. We then selected a limited number of events on the basis of KB goals such as collective decision making and idea synthesis, and we analyzed the potential of SDRA in increasing students' focus on the high-level goals in the KB process.

## Results

### *Participation and domain understanding of the PTs*

We first examined the PTs' participation based on the notes created in KF. The ATK data revealed the PTs' substantial usage of KF; the experimental class and comparison class contributed 1670 and 1444 notes respectively. To investigate the differences in participation between the two class, an independent-samples *t*-test was conducted. A significant difference was obtained between the experimental PTs (mean [ $M$ ] = 39.76, standard deviation [ $SD$ ] = 11.64) and the comparison PTs ( $M = 30.72$ ,  $SD = 9.51$ ),  $t(87) = 4.03$ ,  $p < .01$ . The results suggested that the PIT-aided SDRA

had a positive influence on the PTs' participation, as the experimental PTs participated more in KB inquiry than the comparison PTs.

We conducted another independent-sample *t*-test to investigate the differences in domain understanding between the experimental and comparison PTs. The test revealed a significant difference between the experimental PTs ( $M = 3.50$ ,  $SD = .74$ ) and the comparison PTs ( $M = 3.00$ ,  $SD = .78$ ),  $t(87) = 3.10$ ,  $p < .05$ . The results suggested that PIT-aided SDR had positive impacts on the PTs' domain understanding, as the experimental PTs improved more in domain understanding than the comparison PTs.

### *Characterization of and changes in PTs' collective empowerment*

#### Characterizing the PTs' collective empowerment

##### *Inquiry thread analysis*

The analysis examined the entire inquiry threads to demonstrate the collective, democratic, and sustained nature of the PTs' KB inquiry. As illustrated in Figure 4, the experimental PTs were engaged in collective and democratic KB inquiry; many threads (eg, #3, #15, #16, #17 and #21) involved several students as authors, and no single author dominated the inquiry process. Also, most of the inquiry threads lasted more than 8 weeks, which indicated that the experimental class were engaged in sustained inquiry.

We then qualitatively analyzed all of the inquiry threads of the two classes and used the coding scheme developed by van Aalst (2009) to examine the progressiveness of problem solving and the degree of knowledge advancement through assignment of inquiry threads into three types: knowledge sharing, knowledge construction, and KB/creation (see Table S3). Of the 28 inquiry threads from the experimental class, 4 (14.29%) were classified as knowledge sharing, 8 (28.57%) as knowledge construction, and 15 (57.14%) as KB. Of the 27 inquiry threads from the comparison class, 5 (18.52%) were assigned as knowledge sharing, 12 (44.44%) as knowledge construction, and 10 (37.04%) as KB. These results suggest that the experimental class collectively and progressively solved problems and advanced ideas in the communal space. The comparison class also to some extent also engaged in progressive problem solving and idea improvement collectively.

##### *Analysis of KB discourse characteristics*

This analysis was carried out to qualitatively trace the PTs' questioning, ideation, collective knowledge creation and metacognition by conducting content analysis within each inquiry thread. Table S4 in Supplementary File shows that the discourse created by the experimental PTs was more explanation-oriented than fact-oriented. For instance, more of their questions were aimed at eliciting explanations rather than simple facts (102 notes and 45 notes, respectively), and they contributed more explanations and rise-above notes than they did simple claims (1099 notes, 106 notes, and 87 notes, respectively). The experimental PTs were also able to collectively take up problem-centered ideas from their community (777 notes), and synthesize community ideas (110 notes). Additionally, they were engaged in high-level meta-discourse. The PTs invested much effort in monitoring, reflecting on and planning their collaborative KB. For example, they conducted major reviews of community ideas and inquiry processes (44), and were involved in productive reflections on community ideas as well as their advancement (65). These results suggest that the experimental PTs demonstrated high-level collective empowerment. They generated explanatory questions and elaboration of ideas, contributed diverse ideas to create shared understanding, negotiated a fit between diverse ideas, generated ideas with uptake, and progressively

Table 1: Class differences of collective empowerment: Frequency and percentage of different categories in questioning, ideation, community and metacognition

|                             | Experimental class |                     | Comparison class |                     |
|-----------------------------|--------------------|---------------------|------------------|---------------------|
|                             | <i>f</i>           | % ( <i>f</i> /1602) | <i>f</i>         | % ( <i>f</i> /1434) |
| Questioning                 |                    |                     |                  |                     |
| Explanation-seeking         | 102                | 6.37                | 80               | 5.48                |
| Ideation                    |                    |                     |                  |                     |
| Explanations                | 1099               | 68.60               | 798              | 55.65               |
| Rise-above                  | 106                | 6.62                | 50               | 3.49                |
| Community                   |                    |                     |                  |                     |
| Problem-centred idea uptake | 777                | 48.50               | 504              | 52.84               |
| Synthesizing notes          | 110                | 6.87                | 50               | 11.51               |
| Metadiscourse               |                    |                     |                  |                     |
| Creating awareness          | 124                | 7.74                | 90               | 6.28                |
| Major review                | 44                 | 2.75                | 23               | 1.60                |
| Deepening inquiry           | 65                 | 4.06                | 30               | 2.09                |

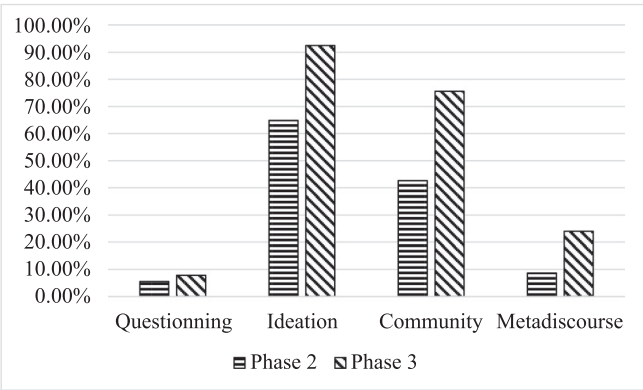


Figure 5: Percentage of notes classified as questioning, ideation, community and metadiscourse in Phase 2 and Phase 3

advanced community ideas through rise-above thinking and by synthesizing, reviewing and reflecting on community ideas.

*Class differences and changes in PTs’ collective empowerment*

To reveal the impact of analytic-supported SDRA on the PTs’ collective empowerment, we first conducted a qualitative analysis to examine the characteristics of the PTs’ notes of the experimental and comparison classes, followed by examining the characteristics of PTs’ notes in Phase 2 (see *Design* under Methods in Phase 2, before analytic-supported SDRA) and Phase 3 (see *Design* under Methods in Phase 3, after analytic-supported SDRA) of the experimental class. We calculated the proportion of notes with high-level discourse moves such as “explanatory questions” (Questioning) and “explanations” and “rise-above” (Ideation) in questions and ideas, which informed the PTs’ collective empowerment, followed by a Chi-square test to examine the possible differences between the two classes and the two phases of the experimental class.

The results of the detailed coding of the notes within the inquiry threads of the two classes are aggregated here to facilitate comparison, as shown in Table 1. Table 1 reveals that the frequency distributions were significantly different between the experimental class and the comparison class,  $\chi^2$  ( $df = 1$ ,  $N = 6072$ ) = 248.41,  $p < .001$ . Primarily, the experimental PTs contributed more explanatory questions and rise-above notes, engaged more in building community knowledge (eg, taking up problem-centered ideas and synthesizing notes), and engaged more in high-level shared metacognition (eg, conducting major reviews and reflecting on and further deepening community ideas) than the comparison-class PTs. These results suggested that analytic-supported SDRA fostered high-level collective empowerment of the experimental class PTs relative to the comparison class.

Figure 5 shows the results for the content analysis of the PTs' notes in Phase 2 and Phase 3 of the experimental class and compares them with the aggregate results. The PTs contributed 985 notes in Phase 2 and 617 notes in Phase 3. A Chi-square analysis revealed that the frequency distributions of high-level discourse moves were significantly different for the two phases,  $\chi^2$  ( $df = 1$ ,  $N = 4806$ ) = 308.19,  $p < .001$ . These results revealed that the PTs in the latter phase demonstrated high-level collective empowerment than that in the early phase, and that the PTs progressively increased their collective empowerment by carrying out analytic-supported SDRA.

#### *SDRA in support of PTs collective empowerment*

We reported the critical events to demonstrate the enacting process of PTs' collective empowerment through SDRA using PIT in KB inquiries. The following are some examples of PTs' analyses and reflections from their prompt sheets, scaffolded by the PIT data. These excerpts come from different groups of PTs.

#### *SDRA using PIT engaging PTs in collective decision making of community ideas*

The following excerpt illustrated how the PIT-aided SDRA fostered students' engagement in choosing and negotiating their ideas collectively:

We collaboratively analyzed again the ideas [in the Idea aggregation window] that have been selected [with the help of the PIT idea tagging function] to reflect on which dimensions we have been discussed well and which dimension have not, and to decide really promising inquires/directions for next-stage inquiry... Our present discussion primarily focuses on *metacognition* and *technologies* [methods and strategies] for personalized learning [Figure 6]. [After analyzing the aggregated ideas], [we] need to further inquire how to use technology to support students' personalized learning, and different teaching strategies and pedagogical models for different students with different ages and needs [followed by a justification explaining why further inquiries into these dimensions were needed]... We will continue our inquiries according to the concept map [their plan, Figure 6]...

In this excerpt, the PTs analyzed the tagged ideas collectively and reflectively with the aim of "[reflecting] on which dimensions we have... discussed well and which dimension [we] have not, and to decide really promising inquires/directions for next-stage inquiry." Their articulation of this aim revealed that the PTs had a sense of choosing ideas with real "promisingness" and that they negotiated among the diverse ideas through collective effort. Building on their present discussion and analysis, the PTs collectively identified promising directions for further inquiry ("how to use technology to support students' personalized learning, and different teaching strategies and pedagogical models for different students with different ages and needs"), and regulated their KB inquiries through generating a detailed research plan that guided their next-stage inquiry (Figure 6). These suggested that PIT-supported SDRA appeared to foster negotiation among different ideas and collective decision making about identifying further inquiries and how to process them.

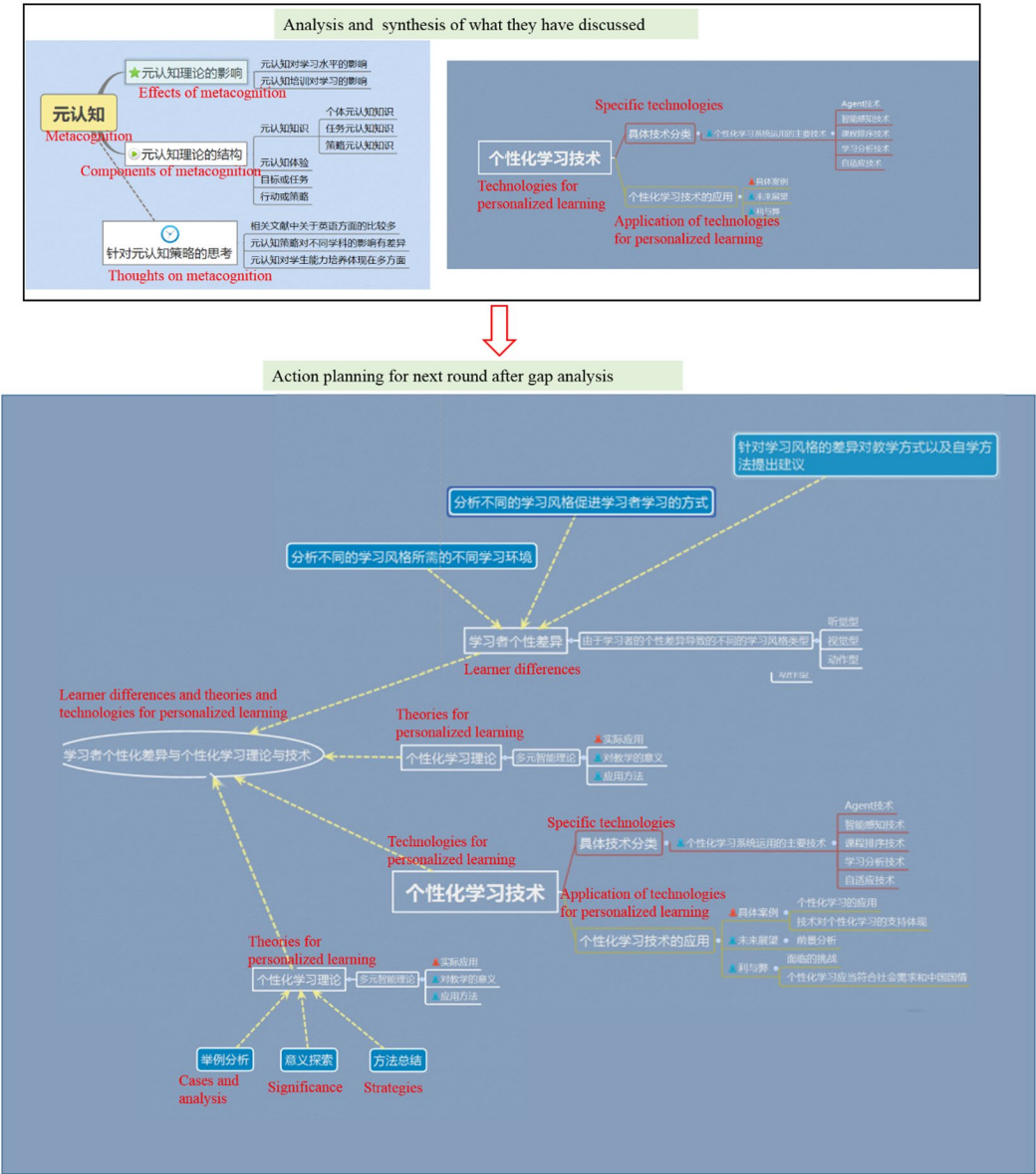


Figure 6: Collective analysis and decision making and plans in PIT-aided SDRA  
[Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

SDRA using PIT engaging PTs in collective idea-synthesis

The following excerpt demonstrated that the process of conducting PIT-aided SDRA helped students to collectively synthesize their community ideas.

We aim to synthesize what we have discussed and decide where we head for next stage... Our present inquiry focus on learning theories, the differences between experts and novices, and in particular transfer of learning (Figure 7). Our discussion on these inquiry topics is not enough. We primarily focus on theories from

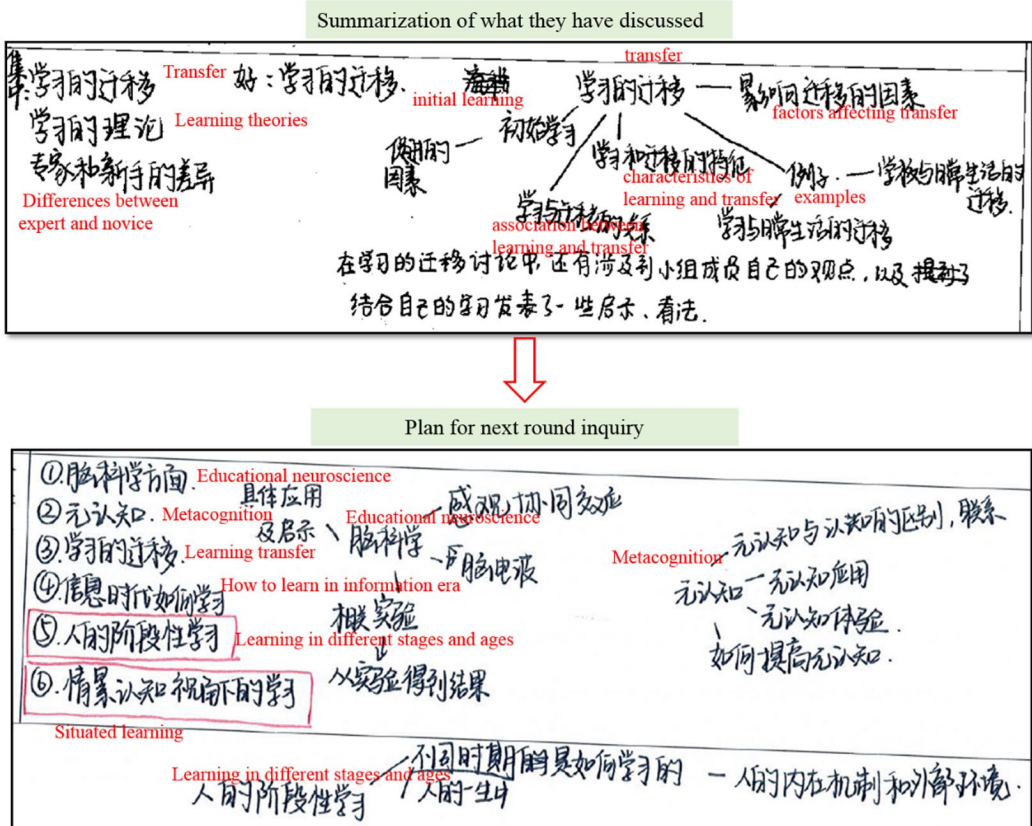


Figure 7: Idea synthesis and plan for next round inquiry  
[Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

others and lack generation of our understanding and theories... Some promising inquiries have not been further discussed... In the further inquiry, our discussion will mainly revolve around learning informed by educational neuroscience, situated learning and learning stages, and metacognition. Specifically, we can deepen our discussion in the following dimensions with our proposal (Figure 7)...

In this narrative, the PTs analyzed and reflected on their discussion based on ideas in the Idea aggregation window of PIT, intending to “synthesize what we have discussed and decide where we head for next stage.” This intention demonstrated that the PTs had realized the importance of synthesizing and extending community ideas and continuously improving ideas. Based on the analysis of the aggregated ideas, the PTs synthesized what they had discussed (“Our present inquiry focus on learning theories...”), and identified gaps that directed further efforts (“our discussion on these inquiry topics is not enough,” “We primarily focus on theories,” “Some promising inquiries have not been further discussed”). The PTs appeared to focus on idea synthesis and improvement; they took actions to address the identified gaps (“our discussion will mainly revolve around learning informed by educational neuroscience, situated learning and learning stages, and metacognition”) and particularly generated a plan (“we can deepen our discussion in the following dimensions with our proposal”) to regulate their further inquiries (Figure 7). It was

encouraging to see that the PTs engaged in idea-synthesis and a progressive deepening of their inquiry with the help of the PIT data.

Overall, the results suggest that conducting PIT-aided SDRAs fostered PTs' collective empowerment as reflected by their collective decision making, their synthesis of ideas, and their "rising above" ideas. The PIT-aided SDRAs facilitated the PTs to orient their learning toward the important goals of their collaborative inquiry in the KB model (eg, collective decision making, synthesis, and rise-above), reflectively and collectively analyze their discussion, and self-direct their further KB inquiries by generating productive plans.

## **Discussion and implications**

This study designed a learning environment that capitalized on KB pedagogy and analytic-supported SDRAs to foster collective empowerment among PTs. We aimed to examine the effects of SDRAs using the Promising Ideas Tool (PIT) on PTs' collective empowerment and the process that allowed these effects to emerge.

### *The impacts of SDRAs on PTs' participation and domain understanding*

Analysis of the PTs' KF database usage showed that the PTs actively participated in KF writing with each PT contributing approximately 40 notes; this is a relatively positive result compared with previous research on KB in higher education (Lei & Chan, 2018; Siqin & Chu, 2019). Comparison of the PTs' participation between the experimental and control class revealed that PIT-aided SDRAs positively influenced the PTs' participation. This result is consistent with previous studies that have revealed positive impacts of SDRAs on learners' participation (Yang *et al.*, 2016; Yang, van Aalst *et al.*, 2020).

Analysis of the PTs' domain understanding showed that the experimental PTs gained more domain knowledge than the comparison PTs. This result suggested that the PIT-aided SDRAs positively affected the PTs' improvement of domain understanding, supporting prior research on the positive effects of SDRAs on improvement of domain knowledge (Yang, 2019; Yang, van Aalst *et al.*, 2020).

### *Characterization of and impacts of SDRAs on PTs' collective empowerment*

Analysis of the PTs' KF discourse indicated that the PTs who exhibited collective empowerment in KB inquiries worked with promising ideas collaboratively and sustainably. They generated discourse that was explanation-oriented and characterized by rise-above thinking. They collaboratively advanced community ideas through social actions, and also reflected on and regulated their inquiry in a shared manner. These results suggested that the PTs became empowered through evidence-supported collective action in collaborative inquiry. They took part in knowledge-related activities in their community (community involvement), collectively worked with ideas as active epistemic agents (community belonging), provided group support in creating knowledge (control of organization), and gradually developed capabilities to deepen and self-direct their inquiry and to work together to contribute knowledge engaged in community building (community building). These findings enriched previous research on the components of collective empowerment (Hur, 2006) by providing an empirical example of it in technology-supported collaborative inquiry.

Comparing the two groups' frequency distributions of KF notes displaying high-level discourse moves, which manifested PTs' collective empowerment, the experimental PTs showed a significantly higher level of collective empowerment than the comparison PTs. The frequency distributions of KF notes manifesting a higher level of collective empowerment also showed a significant improvement of high-level discourse moves in the later stage (after PIT-aided SDRAs) compared

with the early stage (before PIT-aided SDRA). These findings suggested that SDRA using analytics helped the PTs to gradually increase their collective empowerment in KB inquiry. The findings provided empirical evidence for the positive effects of SDRA on empowering learners and are consistent with previous studies that have revealed positive impacts of SDRA on epistemic agency (Yang, 2019; Yang, van Aalst *et al.*, 2020), and productive inquiry and knowledge creation in collaborative inquiry (Raes, Schellens, & De Wever, 2014; White & Frederiksen, 1998; Yang *et al.*, 2016; Yang, van Aalst *et al.*, 2020). These findings offer insights into the relationships among empowerment, metacognition, assessment and instructional practice.

The pedagogy of KB emphasizes scaffolding and the transformative function of “reflective and transformative assessment,” and values students as assets who work as active agents collaboratively and gradually to add value to build knowledge. The design of KB environments augmented by analytic-supported SDRA for empowering learners can make this explicit in a collective KB process; its characteristics are consistent with prior research by Kirk *et al.* (2017) on students’ empowerment. They found that environments designed to empower learners supported students’ productive interaction, mutual support, agency, decision making, and self-directedness and metacognition. The design has important implications for teachers and researchers who aim to design technology-enhanced environments to support learners’ empowerment.

#### *PTs’ enactment of collective empowerment by engaging in SDRA*

Analysis of the PTs’ prompt sheets demonstrated that the use of PIT data and accompanying prompt sheets helped the PTs to increase their collective empowerment by engaging them in on-going collective choice and judgment of promising ideas, analysis of and reflection on idea negotiation, decision making, idea synthesis and action planning of further inquiry. These results suggested that performing SDRA drives PTs to gradually actualize and develop their metacognitive awareness and skills, including gap analysis, ongoing reflection on and regulation of their inquiry, collaboration, idea negotiation and rise-above thinking, all of which are critical to empowering PTs in collaborative inquiry.

In this study, we supported PTs’ engagement in SDRA by providing them with evidence on their inquiry. SDRA is epistemologically similar to other domain-specific inquiries; it does not merely consist of reflection based on opinions, but entails data-informed discourse improvement and problem solving (Yang *et al.*, 2016). We extended SDRA by introducing analytic tools. We also provided the PTs with prompt sheets to guide their analytic-supported SDRA. The prompt sheets were composed of a set of specific metacognitive prompts that guided teachers’ productive reflective assessment, and a metacognitive model that consisted of our analysis, problems, and plan. In the process of conducting SDRA, the PTs may have gradually internalized the metacognitive model, which is critical for increasing empowerment.

#### *Implications for educational practices aiming for increasing learners’ empowerment*

The study has several implications for empowering learners. First, it suggests that productive inquiry is conditioned on establishing a democratic and collaborative learning environment, fostering a sense of community and confidence among learners, and helping students realize their weaknesses. In environments designed to empower learners, learners are perceived as active agents and assets; they inquire, reflect, and build knowledge in a collective manner. Second, it shows that supporting learners’ agency, collective decision making, reflection and regulation, and collective KB are all critical for empowering learners. Third, it shows that learners can benefit from analytic-supported SDRA. However, collaborative reflection opportunities guided by accompanying prompt sheets are needed to aid the learners to engage in productive reflection that effectively integrates face-to-face discussion with online inquiry.

*Limitations and implications for future research*

The study has a few limitations. First, the study focused on PTs' collective empowerment by primarily examining their online discourse; it did not investigate the influence of collective empowerment on the changes in domain knowledge of individual PTs. This study provides evidence of the PTs' collective empowerment in collaborative inquiry and its development over time. However, it does not provide clarity regarding the association among PTs' collective empowerment, individual empowerment, and academic performance. We are designing other studies to examine the role of SDR in increasing learners' empowerment (both individual and collective), and the relationship between empowerment and academic performance.

Second, the study did not utilize the full set of classroom data sources, such as interviews, classroom videos, and face-to-face discourse among PTs and between the teacher and PTs, to characterize the social practices developed around the analytic-supported SDR in KB inquiry. However, understanding the relationship between the dynamics of the social practices developed in the KB process and the online KB inquiry is needed for a clear account of the KB design for empowering learners. Therefore, future studies are necessary to examine the data sources of KB classrooms and to reveal the nature and dynamics of social practices in which analytic-supported SDR is conducted.

**Statements on open data, ethics and conflict of interest**

The data of this study cannot be made openly available due to confidentiality agreements and ethical concerns. The data samples and detailed coding procedures can be accessed by contacting the author.

Ethical approvals were gained from the hosting institution.

This research has no conflicts of interest.

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## Supporting Information

Additional Supporting Information may be found online in the Supporting Information section at the end of the article.