Developing Undergraduates' Collective Epistemic Agency through Reflective Assessment

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Abstract: To examine the effect of reflective assessment on fostering undergraduates' collective epistemic agency, this study adopted a quasi-experimental design. The experimental class included 40 undergraduates conducting inquiries in a KB design enhanced by reflective assessment, while the comparison class included 38 undergraduates experiencing a regular KB design. Students' online Knowledge Forum discourse were collected and analyzed using discourse analysis and social network analysis. The results suggest that undergraduates in the experimental condition took significantly greater levels of collective epistemic agency than the undergraduates in the comparison condition. Groups with different contribution levels can all benefit from reflective assessment within the experimental condition, although they manifest different developmental trajectories. Statistical analysis revealed significant differences in higher-level epistemic and metacognitive actions between high and low contribution groups. These results provide implications for designing technology-rich environments and reflective assessment strategies to support undergraduates' higher-level competencies in Knowledge Building and other computer-supported collaborative inquiry approaches.

Introduction

An important goal of higher education is developing students' high-order competencies to prepare them for the ever-changing knowledge society. Developing these competencies (e.g., metacognition, inquiry, collaboration, and knowledge creation) benefits students' academic performance in the short term and lays solid foundations for their lifelong development (Snell & Lefstein, 2018; Yang et al., 2020a). Computer-supported collaborative inquiry is an influential inquiry model for productive learning and may help students develop these higher-order competencies (Scardamalia & Bereiter, 2014). This model requires students to take high-level collective epistemic agency—students' collective actions for advancing knowledge with intentionality and sustainability (Damşa, 2014; Damşa et al., 2010). However, many students generally take low-level collective epistemic agency when they are not supported. Therefore, developing strategies to promote students' enactment of high-level collective epistemic agency in collaborative inquiry is crucial.

Collective epistemic agency emerged from epistemic agency but was extended by Damsa et al. (2010). Epistemic agency is conceptualized as collective cognitive responsibility to advance knowledge (Scardamalia, 2002). Collective epistemic agency consists of individual and collective intentional, goal-directed and sustained efforts for generating and advancing knowledge with a focus on the collective level (Damsa, 2014; Stahl, 2006; Yang et al., 2020b). This study mainly focused on the collective level of collective epistemic agency. Collective epistemic agency drives students to invest efforts to advance knowledge in collaborative inquiry contexts intentionally. Damsa et al. (2010) suggested that collective epistemic agency includes the epistemic and metacognitive aspects and identified a set of relevant endeavors. The epistemic aspect demands students' intentional and substantial efforts in working with knowledge-related work and engagement in epistemic actions such as generating inquiries, alleviating lack of knowledge, tackling disagreement among diverse ideas, and building joint theory (Borge et al., 2018; Damşa, 2014; Damşa et al., 2010; Oshima et al., 2020; Yang et al., 2019, 2020b). The metacognitive aspect demands students' engagement in a set of metacognitive actions such as setting common goals and creating a joint plan, monitoring object advancement, coordinating object-related activities, and reflections (Damşa, 2014; Damşa et al., 2010; Oshima et al., 2020; Scardamalia, 2002; Yang et al., 2019, 2020a).

Reflective assessment is promising to support students' development of collective epistemic agency in collaborative inquiry learning because it incorporates the metacognitive components (e.g., goal setting and planning, monitoring, reflection, and regulation) into students' inquiry. Research has suggested the positive effects of reflective assessment on students' engagement in collaborative inquiry (Yang et al., 2020a, 2020b). However, relatively few studies have researched how to help undergraduates develop collective epistemic agency by using reflective assessment in computer-supported collaborative inquiry. The current study aimed to address this research gap in Knowledge Building (KB), an influential computer-supported collaborative inquiry approach. KB

advocates transforming schools and classrooms into knowledge-creating communities so that students can practice the above-mentioned competencies on the daily basis (Scardamalia & Bereiter, 2014). To aid students' reflective assessment, we designed visualizations of students' online discourse using Knowledge-building Discourse Explorer (KBDeX, Oshima et al., 2012), a learning analytics tool. This study designed a quasi-experimental study to examine the impacts of reflective assessment on the development of undergraduates' collective epistemic agency in KB. We addressed the following research questions.

1. Did the KB design enhanced by reflective assessment benefit students more in collective epistemic agency than the regular KB design?
2. Did different contribution groups in the KB design enhanced by reflective assessment condition differ in developmental trajectories and collective epistemic agency?

Methods

Research context and participants

This study was conducted in a compulsory core course of literal education titled *Scientific Inquiry and Knowledge Creation* at one research-intensive university in Central China. The course is composed of various theories and practices on developing a set of core competencies (e.g., argumentation, critical thinking, metacognition, and regulation) involved in engaging in scientific inquiry and knowledge creation. It aimed to help undergraduates develop knowledge and high-level competencies of scientific inquiry and knowledge creation, such as taking agency and self-directing their scientific inquiry. The course lasted 18 weeks and had two consecutive 45-minute lessons each week. The participants were 78 undergraduates from 13 faculties who had limited knowledge and skills on how to engage in scientific inquiry and knowledge creation. This study used a quasi-experimental design; the experimental class (40) conducted KB inquiries in a KB design enhanced by reflective assessment. The comparison class (38) was involved in a regular KB design. Both classes were taught by the course instructor who had expertise in designing KB environments and guiding students in KB inquiries.

Pedagogical design

We designed a four-components co-directed inquiry model with a set of principle-based activities to help the undergraduates progressively develop high-level collective epistemic agency in KB inquiries. The four phases were: (1) culture for cultivating self-directness and collaborative inquiry (component 1, Weeks 1-3); (2) enacting collective epistemic agency by reflective assessment using group-level visualizations and data (component 2, Weeks 4-9); (3) enacting collective epistemic agency by reflective assessment using community-level KBDeX data (component 3, Weeks 10-13); and (4) developing higher-level collective theories and collective epistemic agency through pervasive reflective assessment (component 4, Weeks 14-18). Our design was informed by the three-phased KB process model (Yang et al., 2020b) and the computer-supported group regulation framework (Borge et al., 2018).

Instruction in the comparison class

The comparison group of undergraduates conducted the same KB inquiries with the support of the same instructor as that of the experimental group. In Component 1, they conducted the same activities and tasks at the same pace. In Components 2 and 3, the experimental class used KBDeX visualizations and data to conduct reflective assessment. However, the comparison group was guided to enact collective epistemic agency by conducting collective portfolio assessment (van Aalst & Chan, 2007) using their own group's notes in Component 2. In Component 3, they used their own and other groups' notes. In Component 4, the comparison undergraduates were encouraged to conduct the portfolio assessment to further synthesize and rise above their theories. Otherwise, the two classes experienced the same KB tasks and activities.

Data sources and analysis

The experimental and comparison class generated 1,689 and 1,082 Knowledge Forum notes were the main data source to understand the characteristics and development of undergraduates' collective epistemic agency. We argued that their competency reflects the undergraduates' collective epistemic agency to improve their collective KB discourse. Creating higher-level ideas and engaging in higher-level epistemic and metacognitive actions to advance community knowledge represents their higher-level collective epistemic agency in KB inquiries.

We first pre-processed undergraduates' Knowledge-Forum notes into different discussion threads through thematic analysis. A discussion thread is a cluster of notes targeting the same principal problem (Zhang et al., 2007). Next, we conducted content analysis of all notes within each inquiry thread using the coding

framework presented in our previous work (Yang et al., 2019; Yang et al., 2020b). We included different categories that illustrated epistemic and metacognitive actions. The first author and another researcher who had expertise in analyzing KB notes independently coded 600 notes of the experimental class ($n = 600$, >30%). The two researchers reached inter-rater reliability (Cohen's kappa) of .83 for epistemic actions and .84 for metacognitive actions.

Results

Impacts of reflective assessment on undergraduates' collective epistemic agency

To investigate the effects of reflective assessment on undergraduates' collective epistemic agency, we first examined the differences in collective knowledge advancement between the experimental and comparison class, followed by examining the difference of Knowledge-Forum notes coded as epistemic and metacognitive actions. We proposed that undergraduates' collective epistemic agency was characterized by collective knowledge advancement through epistemic and metacognitive KB actions.

Differences and changes of collective knowledge advancement

The state of collective knowledge is reflected by a network of ideas created by students (Oshima et al., 2012). Therefore, the increasing number of meaningful links between ideas is a measure of collective knowledge advancement. In social network analysis, degree centrality indicates cumulative path lengths by which a node is linked to other nodes in a network; hence, a higher Total Degree Centrality (TDC) represents a denser social network. For instance, an increased TDC for note network over time denotes how students collectively worked on key ideas. Therefore, TDC derived from KBDeX has become a common tool to assess collective knowledge advancement (Oshima et al., 2017; Oshima et al., 2018). Based on this assumption, we compared the increase in the TDC of both classes to assess the differences in collective knowledge advancement.

Figure 1 shows the increasing TDC of note networks over time, indicating how students collectively worked on their Knowledge Forum discourse. In Stage 1, a one-way ANOVA showed no significant difference of the collective knowledge advancement between the experimental and comparison classes, ($F(1, 8) = 1.89$, $p = .207$, $\eta^2 = .19$). In contrast, significant differences were observed in favor of the experimental class in Stage 2 ($F(1, 12) = 8.20$, $p = .014$, $\eta^2 = .41$) and in Stage 3 ($F(1, 4) = 165.42$, $p < .001$, $\eta^2 = .98$) when the reflective assessment intervention was implemented. These results indicated that the experimental class engaged in higher-level collective knowledge advancement with the support of reflective assessment compared with the comparison class.

Figure 1

Total degree centrality of discourse network for experimental and comparison classes over time
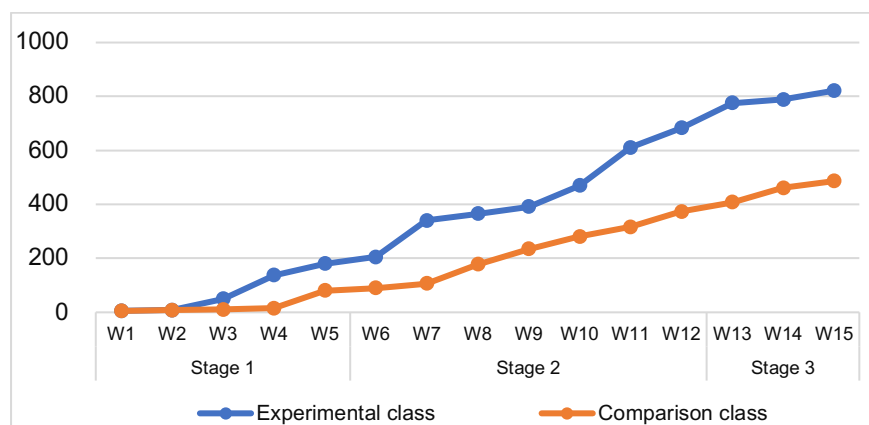
Note. Here, W = Week; Week 1 started from the beginning of note writing on Knowledge Forum.

Class differences in undergraduates' epistemic and metacognitive actions

To examine the differences of epistemic and metacognitive KB actions between the experimental and comparison classes, we calculated the portions of each KB action and conducted a Chi-square test to assess the differences between the two classes. Table 1 compares the metacognitive and epistemic actions of the two classes.

There were significant differences between the experimental and comparison classes regarding the portions of different epistemic and metacognitive actions [χ^2 ($df = 1$, $n = 5542$) = 90.56, $p < .001$]. The experimental class took more higher-level epistemic actions than the comparison class. For example, they engaged in more *developing shared understanding* (39.25% vs. 35.03%), *engaging problem-centered uptake* (25.40% vs. 16.82%), *building a joint theory* (4.97% vs. 3.14%), and s*ynthesizing and rising above community ideas* (4.50% vs. 2.50%) than the comparison undergraduates. Also, the experimental undergraduates conducted more collectively regulating inquiry (12.26% vs. 5.82%), and more higher-level actions of constructing reflective synthesis notes, including *meta-theory* and *meta-conversation* (3.02% vs. 1.48%) than the comparison undergraduates. These results suggested that reflective assessment exerted positive impacts on undergraduates' epistemic and metacognitive actions.

Table 1

Classroom differences in epistemic and metacognitive actions: Frequency and percentages of actions by the experimental and comparison classes

	Experimental Class		Comparison Class	
	f	% (f/1689)	f	% (f/1082)
Epistemic actions				
Creating inquiry awareness	62	3.67	57	5.27
Alleviating lack of knowledge	328	19.42	277	25.60
Negotiating a fit	47	2.78	126	11.65
Developing shared understanding	663	39.25	379	35.03
Engaging problem-centered uptake	429	25.40	182	16.82
Building a joint theory	84	4.97	34	3.14
Synthesizing and rising above community ideas	76	4.50	27	2.50
Metacognitive actions				
Collectively regulating inquiry	207	12.26	63	5.82
Generating brief introduction	13	0.77	6	0.55
Generating meta-cognition	25	1.48	4	0.37
Contributing meta-theory	15	0.89	4	0.37
Contributing meta-conversation	36	2.13	12	1.11

Differences in collective epistemic agency among different contribution groups

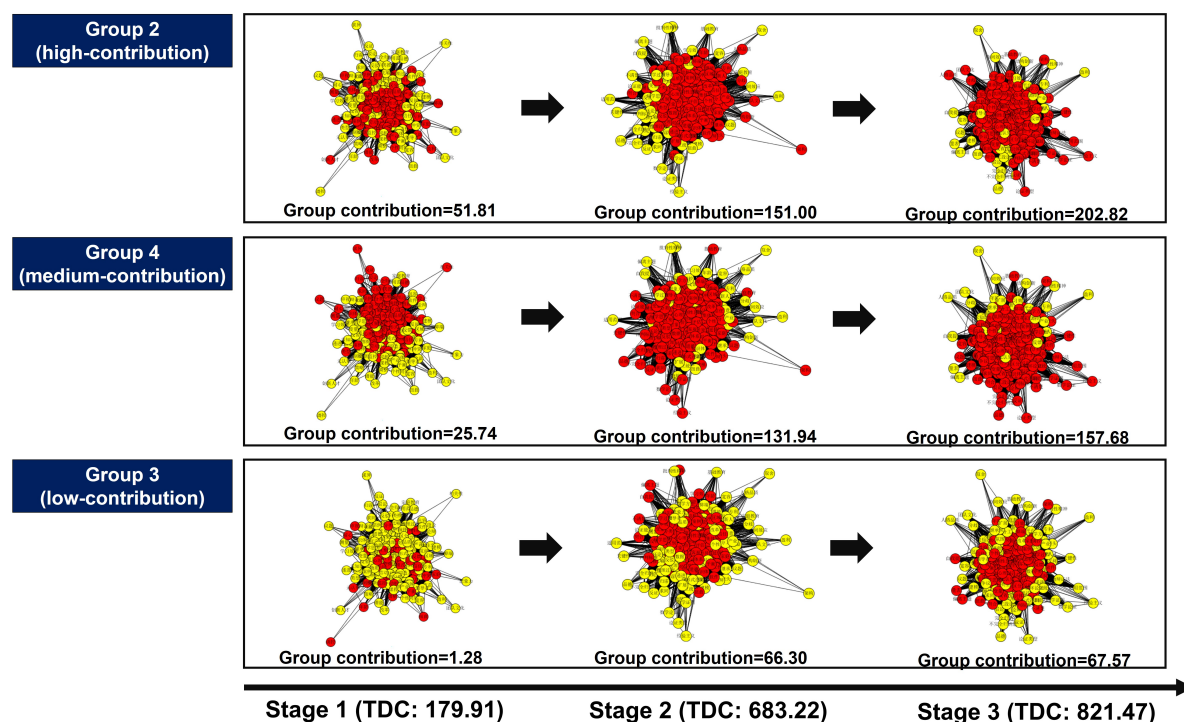### Developmental trajectories of collective knowledge of different contribution groups

To further reveal the group differences in collective epistemic agency, we selected a high-, medium-, and low-contribution group in the experimental class and examined their development trajectories of collective knowledge by using KBDeX discourse networks to track their Knowledge Forum notes. The high, medium, and low-contribution groups were differentiated by the extent to which their Knowledge Forum notes added value to the TDC of the whole class.

Figure 2 presents the changing word networks of a high-, medium-, and low- contribution group, respectively. The red circles represent the keywords discussed, while the yellow circles denote words not discussed. The figure shows that each contribution group contributed more in Stage 2 than in Stage 1 and 3. For example, the high-contribution group increased the TDC value from 51.81 in Stage 1 to 151.00 in Stage 2, and finally to 202.82 in Stage 3. These findings were consistent with the paired-samples t-tests results (RQ1), suggesting undergraduates' greater contributions to collective knowledge advancement in Stage 2 with the support of reflective assessment. Specifically, in Stage 1, when the undergraduates deepened their knowledge building inquiries with group-level KBDeX data, the high-contribution group presented a centralized network of red circles, demonstrating their ability to connect subtopics. The medium-contribution group showed a marginal network of red circles, displaying their relatively weak ability to conceptualize the subtopics across the whole community.

Furthermore, the low-contribution group showed distributed clusters of red circles, suggesting they explored different subtopics but made limited connections between the subtopics. In Stage 2, with the support of reflective assessment using community-level KBDeX data, all the three groups obviously advanced their collective knowledge compared with Stage 1. Specifically, the high-contribution group effectively conceptualized the community ideas, while the medium and low contribution groups began to map collective ideas. In Stage 3, all the three groups constantly contributed to collective knowledge advancement to varying degrees, showing their ability to advance collective knowledge even though the corresponding tools were withdrawn. These results suggest the role of reflective assessment in scaffolding different contribution groups for collective knowledge advancement.

Figure 2

Changing networks and group contributions to collective knowledge advancement of the experimental class over stages

Group 2 (high-contribution)		
Group contribution=51.81	Group contribution=151.00	Group contribution=202.82
Group 4 (medium-contribution)		
Group contribution=25.74	Group contribution=131.94	Group contribution=157.68
Group 3 (low-contribution)		
Group contribution=1.28	Group contribution=66.30	Group contribution=67.57
Stage 1 (TDC: 179.91)	Stage 2 (TDC: 683.22)	Stage 3 (TDC: 821.47)

Epistemic and metacognitive actions used by different contribution groups

Figure 3 presented the percentage of epistemic actions and metacognitive actions by different contribution groups of the experimental class. We regrouped all the undergraduates in the six working groups into three contribution groups based on the extent to which their Knowledge Forum notes added value to the TDC of the whole class: high-rank group (13 undergraduates), medium-rank group (14), and low-rank group (13).

Figure 3 shows that all the contribution groups manifested the ability to take higher-level epistemic actions including developing shared understanding (E4, around 40%), engaging in problem-centered uptakes (E5, around 25%), building joint theories (E6, around 5%), and synthesizing and rising above community ideas (E7, around 5%). We also found that all the contribution groups displayed the same ability in collective regulation of KB inquiry (M1, around 70%), but different abilities in taking other metacognitive actions. Notably, the high-rank group showed a higher level of contributing meta-theory (M4, 8.40%) than the medium-contribution group (5.00%), while the low-contribution groups rarely contributed meta-theory (0.00%). In contrast, the low-rank groups contributed more than two times of meta-conversation (M5, 22.08%) than the high-contribution groups (9.24%). These results suggest that all contribution groups, even the low-rank group, could engage in higher-level epistemic and metacognitive actions to collectively advance their KB inquiry and ideas with the support of reflective assessment.

A one-way MANCOVA was then adopted to examine the differences of the epistemic and metacognitive actions by the three contribution groups, revealing a significant difference, $F(22, 54) = 1.82$, $p = .038$, Wilks' Λ = .33; partial eta^2 = .43. Follow-up univariate ANOVAs show significant differences in developing shared understanding ($F(2, 37) = 6.18$, $p = .005$, partial eta^2 = .25) and contributing meta-theory ($F(2, 37) = 9.48$, $p < .001$, partial eta^2 = .34). Post hoc statistical results indicate that the high-rank group displayed significantly higher values of epistemic action of developing shared understanding ($p = .007$) and metacognitive action of contributing meta-theory ($p < .001$) than low-rank group, as well as higher values of developing shared understanding ($p = .022$) than medium-rank group. These results suggest that the high-rank group engaged in more higher-level epistemic and metacognitive actions.

To sum up, the undergraduates could engage in epistemic and metacognitive actions with the support of reflective assessment. The high-rank group engaged more in higher-level epistemic and metacognitive actions than their counterparts.

Figure 3
Percentages of epistemic and metacognitive actions by different contribution groups in the experimental class
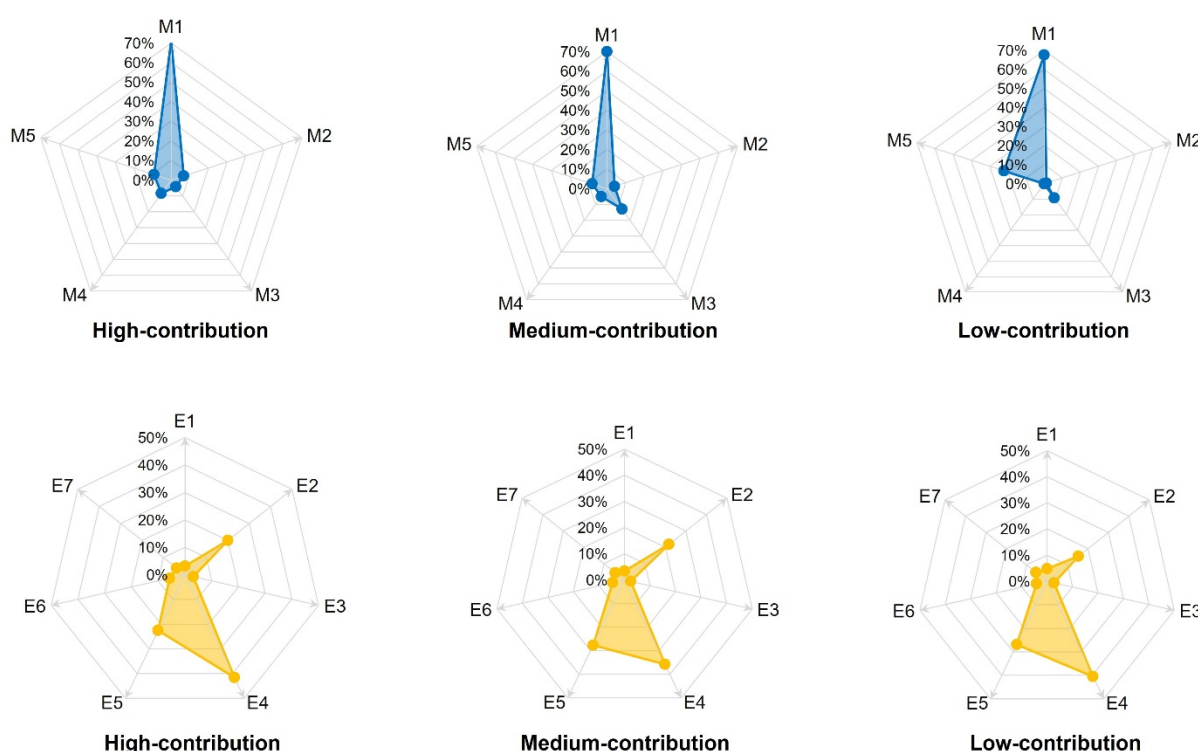
Notes. *Metacognitive actions*: M1=*collectively regulating inquiry*; M2=*generating brief introduction*; M3=*generating meta-cognition*; M4=*contributing meta-theory*; M5=*contributing meta-conversation*. *Epistemic actions*: E1=*creating inquiry awareness*; E2=*alleviating lack of knowledge*; E3=*negotiating a fit*; E4=*developing shared understanding*; E5=*engaging problem-centered uptake*; E6=*building joint theory*; E7=*synthesizing and rising above community ideas*.

Discussion

Increasing students' collective epistemic agency is one key goal of KB and scientific practice. Reflective assessment has the potential to facilitate undergraduates' collective epistemic agency because it incorporates the metacognitive components of planning, monitoring, reflection and regulation into students' inquiry. This study aimed to examine the impacts of reflective assessment on undergraduates' collective epistemic agency and the dynamics of how reflective assessment support collective epistemic agency by adopting a quasi-experimental design. The undergraduates in the experimental condition engaged in a KB design enhanced by reflective assessment while the students' in the comparison class experienced a regular KB design.

Impacts of reflective assessment on undergraduates' collective epistemic agency

This study shows that the experimental undergraduates engaged in a significantly higher level of collective knowledge advancement and epistemic and metacognitive actions than the comparison undergraduates. This result suggests the positive impacts of reflective assessment on students' development of collective epistemic agency in KB. Similarly, previous research suggests the positive effects of reflective assessment on students' epistemic agency (Yang et al., 2019, 2020b), higher-level competencies, and domain understanding (Borge et al., 2018; Yang et al., 2016, 2020a).

The analysis of the trajectories of collective knowledge of different contribution groups suggested all the groups could make contributions to collective knowledge advancement over time, particularly in the reflective assessment process, though their development paths differ. They sharply advanced collective knowledge with the support of reflective assessment and still manifested the ability to advance collective knowledge when the reflective support faded out later. These results indicated the scaffolding function and transformative role of reflective assessment in collective knowledge advancement for all contribution groups. These results are consistent with prior studies examining the role of reflective assessment on students with varying academic performance (Yang et al., 2016, 2020a).

All the contribution groups could engage in high-level epistemic and metacognitive actions. However, the high-contribution group engaged significantly more in developing shared understanding and contributing meta-theory. Notably, the low-contribution group contributed significantly more meta-conversation than the high-contribution group. Also, both high and medium-contribution groups took more higher-level epistemic actions compared, which might explain why the undergraduates could still advance collective knowledge after the reflective assessment process. These results suggested that the contribution groups took different levels of epistemic and metacognitive actions, though all the contribution groups could take higher-level actions with the help of reflective assessments. Particularly, low-contribution groups obtained greater net gains in terms of the ability to generate meta-conversations, the highest level of metacognitive actions, providing further evidence of the scaffolding role of reflective assessment for students with relatively lower performance (White & Frederiksen, 1998). Partially aligned with previous studies (Li et al., 2020), this study indicated that different contribution groups did not differ in generally low-level epistemic and metacognitive actions but showed significant differences in higher-level actions. The high performer could regulate their efforts in a way that maximizes outcomes with the least effort rather than stay highly engaged in the whole learning process (Li et al., 2020).

Implications for Educational Practices to Help Students Enact Epistemic Agency.

The study provides several implications for educators to design technology-rich environments to foster students' collective epistemic agency in collaborative inquiry. First, the extent to which students can benefit from reflective assessments, particularly at the initial stage, relies on their opportunities to engage in meta-level talks. These meta-level talks, which integrate face-to-face group level reflections with online Knowledge Forum inquiry, benefit students' successful reflective assessment. Second, in collaborative inquiry, teachers should allow the presence of relatively lower-level metacognitive actions that is an integral part of students' everyday inquiry practices. Moreover, higher-level metacognitive actions are critical for productive collaborative inquiry and do not often take place naturally, so appropriate scaffolding strategies are needed to promote them. Third, the provision of data from learning analytics can help students develop a deep understanding of their inquiry. Reflective prompt sheets designed for productive use of learning data are also fundamental, which help students gradually internalize the metacognitive model embedded in the prompt sheets. Therefore, even when reflective assessment support fades out, students can still engage in metacognitive activities and advance their collective knowledge.

Limitations and Implications for Future Research

This study has several limitations that need to be addressed in future research. First, the study did not investigate undergraduates' domain understanding changes. The study revealed the positive effects of reflective assessment on the undergraduates' collective epistemic agency in Knowledge Building inquiry, but whether those changes are transferable is not clear. Future research can examine whether and how reflective assessment and KB empower students to develop domain understanding and other future-ready competencies self-directedness.

Second, the undergraduates' epistemic agency analysis relied on their written Knowledge Forum notes. Further research may explore the use of wearable devices and eye-tracking to understand undergraduates' epistemic agency even when they do not write. Moreover, much work remains to be done particularly from the educational neuroscience perspective, to unpack the mechanisms of epistemic agency and its collection to performance, engagement, and learning.

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Acknowledgment