Examining the role of metadiscourse in collaborative knowledge building community

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Abstract

Purpose – Metadiscourse is an important dialogue technique used in productive knowledge building to help a group evaluate and advance their knowledge progress. Previous studies have identified and defined various types of metadiscourse. However, there is scant knowledge about how different metadiscourse types emerge among different groups or what implicit correlations lie between progressive discourse and metadiscourse. Moreover, research on how different types of metadiscourse influence groups' knowledge advancement and artifacts is still inadequate. Therefore, this study aims to further examine the roles that different types of metadiscourse play in the collaborative knowledge building community on both a fine-grained (i.e. progressive discourse) and coarse-grained (i.e. group knowledge advancement and group artifacts) level.

Design/methodology/approach – Data for this study are drawn from the behaviour of undergraduate students participating in a 12-week course at a key university in China. On the fine-grained level, epistemic network analysis (ENA) is applied to illustrate how metadiscourse promotes the development of progressive discourse. On the coarse-grained level, two different chi-square tests are conducted to examine the roles of different types of metadiscourse in groups' knowledge advancement and artifacts.

Findings – The analysis allowed several conclusions to be drawn. First, the types of metadiscourse that students most often adopted were reflecting on ideas development (RD) and commenting on ideas (CI); they less frequently adopted setting group goals (SG) and making group plans (MP). Second, most types of metadiscourse correlated with developments in progressive discourse, particularly RD and CI. Third, the metadiscourse types RD, CI and coordinating group efforts (CE) played essential roles in knowledge advancement. Fourth, higher-quality artifacts could be created by using the metadiscourse type reviewing the state of knowledge building progress (RP).

Originality/value – A more profound comprehension of the role that metadiscourse plays in the collaborative knowledge building community not only contributes to the literature in the knowledge building field but also carries a significant meaning in regulating community, promoting learner agency and sustained knowledge, and consequently improving collaborative learning performance.

Keywords Metadiscourse, Knowledge building, Collaborative learning, Collaborative learning analytics

Paper type Research paper

1. Introduction

Education in the knowledge age requires students to learn how to contribute to the knowledge creation process so they can grow into competent members of the knowledge society (Bereiter, 2002; Chen and Hong, 2016). To learn how to effectively contribute,

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knowledge building theory provides a framework for teaching students how to work together creatively and effectively to advance group knowledge, and thus establish a fruitful knowledge society.

Knowledge building emphasises two types of discourse—progressive discourse and metadiscourse—as the mediums through which community knowledge is constructed (Bereiter and Scardamalia, 2014; Chan *et al.*, 2019). First, members of a knowledge building community will contribute and develop ideas through progressive discourse (Tong and Chan, 2021), which is associated with the developmental nature of knowledge and ideas (e.g. contributing diverse ideas and advancing ideas). Second, to keep up and further promote progressive discourse, members need to enact learner agency autonomously (Zhang *et al.*, 2022) by engaging in metadiscourse.

Metadiscourse is a "discourse about a discourse" (Simmons, 1993). In other words, metadiscourse refers to intense discussions about the progress and difficulties in the main knowledge-creation effort (Bereiter and Scardamalia, 2014, p. 46). For example, it considers questions such as "Are we getting stuck?" or "How can we move forward?" Members of the knowledge building community use this important discourse (Bereiter and Scardamalia, 2016; Yang *et al.*, 2022a) to co-design and co-direct their ongoing inquiry toward task objectives via metacognitive cycles of task analysis, monitoring and reflection, and inquiry regulation (Resendes *et al.*, 2015; Ben-Eliyahu, 2019; Yang *et al.*, 2020a).

In the past decades, researchers have paid increasing attention to metadiscourse in the knowledge building context (van Aalst, 2009; Chan, 2011; Zhao and Chan, 2014). Previous studies identified different definitions for metadiscourse (Resendes *et al.*, 2015; Bereiter and Scardamalia, 2016; Lei and Chan, 2018; Zhu and Lin, 2023) and some types of metadiscourse (Zhao and Chan, 2014; Bereiter and Scardamalia, 2016). However, it is unknown to what extent different types of metadiscourse emerge among different groups (Khosa and Volet, 2014) and what implicit correlations lie between progressive discourse and metadiscourse. Moreover, the ways in which different types of metadiscourse influence groups' knowledge advancement and artifacts (e.g. group products, such as papers and reports) are still not fully understood.

Consequently, this study focuses on the following three research questions:

RQ1. How do progressive discourse and metadiscourse emerge in different collaborative knowledge building communities?

RQ2. How does metadiscourse promote the development of progressive discourse?

RQ3. What are the roles of the different types of metadiscourse in groups' knowledge advancement and artifacts?

2. Literature review

2.1 Knowledge building and knowledge forum (KF)

Knowledge building is a social-constructivist approach to preparing students to participate in a knowledge society (Hong *et al.*, 2019a, b; Chai and Zhu, 2021). This approach is regarded as a theoretical, pedagogical, and technological innovation (Scardamalia and Bereiter, 2010) that traces its theoretical foundations to Social Constructivism Theory (Gergen, 1992) and Three Worlds Theory (Popper, 1979).

In knowledge building, ideas are viewed as real things that can be the object of discourse. Through this discourse, students work collaboratively, creatively, and innovatively with ideas (Hong and Lin, 2019). Given the unpredictability of idea improvement, a principle-based pedagogical design is employed to enable the sustainable development of ideas (Hong *et al.*, 2019a, b). These twelve principles, including *idea diversity, real ideas, authentic problems,* and

improvable ideas, distinguish knowledge building from procedure-based approaches and benefit the students by encouraging them to work adaptively and with full flexibility to construct their self-generated ideas (Zhang *et al.*, 2011; Chai and Zhu, 2021).

To ensure teachers and students can fully grasp the above principles, a networked software environment called the Knowledge Forum (KF) provides a platform through which to engage in continuous idea improvement. KF supports translating the principles into practice and helps make those principles more apparent to teachers and students, thus further enriching community knowledge.

It is expected that members of the same KF community will share common goals and interests. To achieve these shared goals, members will identify and work on understanding-related problems jointly, putting out diverse ideas in the form of public notes, promoting continuous progress, and producing new knowledge. Students can also employ various resources, such as books, videos, online information, and personal experience, to enhance community knowledge in this environment.

In summary, knowledge building aims to bring the goals and process of knowledge creation communities into the education environment so students can learn how to participate in a knowledge society. Knowledge building theory, evolving with the new KF environment, is instantiated with principle-based pedagogy designed to mirror and support the process of creative expertise (Chan and van Aalst, 2018). This approach provides a straightforward way to address the contemporary emphasis on knowledge creation and innovation.

2.2 Metadiscourse and progressive discourse in knowledge building

In a collaborative knowledge building community, progressive discourse and metadiscourse are the mediums through which community knowledge is constructed (Lei and Chan, 2018). Progressive discourse emphasises interactions at the ideational level ("toward ideas"). In other words, it focuses on developing ideas, including "contributing ideas, advancing ideas, achieving shared understanding, and rising above" (Zhu *et al.*, 2022). Supported by KF, students engage in this ideational-level discourse, posting ideas, generating questions, and explaining their reasoning. As the above process illustrates, progressive discourse is dynamic (Bereiter, 1994; Nennig *et al.*, 2023). That means when students with different views engage in discourse, it can lead to a new understanding that everyone involved agrees is superior to their prior understanding (Clarà, 2019).

On the other hand, metadiscourse stresses the metacognitive strategies that individuals use to communicate with group members to identify goals, make plans for further inquiry, and collectively monitor community knowledge development (Khosa and Volet, 2014; Zheng *et al.*, 2019). It thus supports group members' collaborative efforts to achieve task goals ("toward tasks").

Previous studies identified different subcategories of metadiscourse in collaborative knowledge building communities. Bereiter and Scardamalia (2016) proposed that metadiscourse includes the following types: *the present state of knowledge development*, *the present state of the knowledge building effort*, *the present state of the community*, and *the next steps*. Additionally, Oshima *et al.* (2020) found students regulated their collaborations by (1) setting goals and making feasible plans; (2) reflecting on and monitoring their progress; and (3) solving conflicts using critical feedback to chart a new course and make space for others' contributions.

However, these studies only identified functional elements of metadiscourse without providing more detailed descriptions of the associated processes and indicators. These studies also lacked insight into how metadiscourse emerges within collaborative knowledge building communities, as well as into the implicit correlations that exist between metadiscourse and progressive discourse. Thus, a more detailed and operational

framework is required to identify the functional elements of metadiscourse in real-life settings and to determine how they are used during discourse, which ideally should help elucidate the implicit correlations between metadiscourse and progressive discourse.

To conclude, knowledge building discourses not only promote ideas development (i.e. progressive discourse), but they are necessary to maintain the relationship between ideas development and knowledge goals (i.e. metadiscourse). These two types of discourse are intertwined together to achieve task goals. Of these two discourse types, metadiscourse has received more attention in recent studies. But a detailed and operational framework for metadiscourse is still lacking. This gap must be addressed if more educators are to adopt knowledge building practices into their classrooms.

2.3 The role of metadiscourse in groups' knowledge advancement and artifacts

Previous studies on knowledge building emphasised the importance of using metadiscourse to continually promote knowledge advancement during knowledge building. For example, Lei and Chan (2018) examined the role and nature of metadiscourse and showed that it was associated with higher levels of knowledge advancement and more sustained inquiry when metadiscourse involves collective processes. Specifically, the significance of metadiscourse in connecting students' discourse was highlighted (Bereiter and Scardamalia, 2014; Wu and Yang, 2022). In this way, metadiscourse was identified as a critical technique for students to deepen inquiry and promote knowledge advancement (Zhang *et al.*, 2011; Yang *et al.*, 2022a).

Additionally, some studies investigated the effect of metadiscourse on the performance of group artifacts. Group artifacts, also called group products, are created by groups or communities using tools such as KF, wikis, and mind maps. The resulting artifacts include project reports, papers, business plans, and technology tools (Zheng *et al.*, 2019). For example, Tong (2020) designed and implemented a metadiscourse-oriented knowledge building environment to scaffold students' collaborative engagement in metadiscourse. Analysis of results within Tong's environment showed that students who are more engaged in metadiscourse would better understand concepts and improve artifact performance in knowledge building. Similarly, reflective assessment tools were used in a study by Yang *et al.* (2020a) to facilitate metadiscourse, indicating that metadiscourse could foster students' engagement, thus improving their academic performance (e.g. KF writing).

In conclusion, previous research has underlined the significance of metadiscourse in group knowledge progression and artifacts. However, less attention was given to how the application of different types of metadiscourse might influence a group's knowledge advancement and artifacts. It is, therefore, necessary to explore the differences in the types of metadiscourse used by groups, considering their knowledge advancement and artifacts. With this knowledge, more suitable scaffoldings or prompts could be provided to facilitate students' knowledge advancement and improve the performance of their artifacts.

3. Research methodology

3.1 Participants

An exploratory case study was conducted to examine the role that metadiscourse plays in the collaborative knowledge building community. Thirty-five second-year undergraduate students (9 males, 26 females) participated in a 12-week course called "Knowledge Building and Collaborative Innovation" at a key university in Guangzhou, China. The participants were from several schools within the university, majoring in history education, math education, educational technology, and geography. Notably, they did not have previous experience in knowledge building. This course aimed to develop students' knowledge creation competency by having them engage in knowledge building activities.

Participants were randomly divided into six groups ($NG_1 = 6$; $NG_2 = 5$; $NG_3 = 6$; $NG_4 = 6$; $NG_5 = 5$; $NG_6 = 7$). The instructor had a Ph.D. in education technology and six years of teaching experience using the knowledge building approach.

3.2 Course design and implementation

The course consisted of three phases and lasted for 12 weeks. In Phase 1 (weeks 1–3), the instructor introduced the background, KF, and 12 knowledge building principles. To assist the students in comprehending the concepts and drawing connections between the concepts and KF affordances, several video lectures were recorded and made available in KF.

Phase 2 (weeks 4–10) was about engaging participants in group activities with the aid of the KF. Each group attempted to create an artificial intelligence (AI) product or come up with a solution to a particular AI problem using knowledge building discourse. In Phase 3 (weeks 10–12), each group designed and presented PowerPoint presentations on their group AI product or solution.

Two platforms were employed to support blended learning, including a Moodle-based learning platform and KF. Every week before class, the students used the Moodle-based learning platform and KF to watch videos online, read articles, and engage in online discussions. The Moodle-based platform was primarily used for managing classes, including the distribution of instructional materials, the posting of announcements, and the submission of final assignments. KF was mostly used by students to cooperate on group assignments (i.e. AI-related products or solutions).

The scaffolds were customised by the teacher (e.g. sharing information, integrating and improving ideas, and negotiating ideas). Throughout the class, the instructor verified the students' comprehension of the online materials and led discussions about any difficulties raised by the students as they read the materials. After class, the students continued participating in group projects and online discussions via the KF.

3.3 Data collection and analysis

The KF notes and final group artifacts served as the data sources for this study. Data were collected from the KF notes throughout the 12 weeks to determine the students' use of metadiscourse.

3.3.1 Developing coding framework of discourse in knowledge building community. Metadiscourse can be considered a medium for group metacognition (Biasutti and Frate, 2018), i.e. a state in which group members have collective awareness of the tasks, ideas, products, and group atmosphere. In this case, metadiscourse can be divided into four aspects: tasks-centred, ideas-centred, products-centred, and group-centred (Whitebread *et al.*, 2009; Ouyang *et al.*, 2022; Zhu *et al.*, 2022).

Tasks-centred metadiscourse involves setting goals for each task and making appropriate and feasible plans. Idea-centred metadiscourse includes attending to and being aware of the development of ideas, plus commenting on ideas. Product-centred metadiscourse involves "appraising the performance" and includes evaluating the products to check whether their performance meets the requirements for a task. Group-centred metadiscourse means that members take responsibility for fostering a collaborative and creative climate by coordinating the group efforts and inviting participation.

In addition to the four metadiscourse aspects described above, subcategories of the cognitive aspect in Zhu *et al.*'s (2022) study were adopted in this study to categorise progressive discourse.

Based on the above coding structure, two researchers analysed knowledge building discourse curated from the KF notes and final group artifacts using a combination of deductive and inductive approaches (Armat *et al.*, 2018; Saldaña, 2021). During this analysis,

several subcategories of metadiscourse were identified in accordance with group metacognition theory and were also identified in the original notes. A coding framework was developed consisting of two categories and 12 subcategories. Descriptions of these codes are shown in Table 1.

3.3.2 Methods for assessing knowledge advancement. To represent groups' knowledge advancement, cumulative degree centrality (CDC) was employed in this study. This indicator has been used to assess collective knowledge advancement (Oshima *et al.*, 2012), meaning the degree to which each key term in the overall network is connected to other key terms ("Key terms" are terms that are closely related to a specific task for each group in the inquiry thread.) In this way, the cumulative degree centrality of a note network will, over time, reflect how students worked collectively on key terms (Oshima *et al.*, 2012) and thus indirectly indicate their groups' knowledge advancement.

Specific analysis processes are as follows. Two researchers initially screened and negotiated key terms related to each group's AI project and then used the Knowledge Building Discourse Explorer (KBDeX), a platform for exploring discourse in collaborative learning (http://www.kbdex.net), to calculate the cumulative degree centrality (see Figure 1).

3.3.3 Rubric of groups' artifacts. To assess the groups' artifacts, an analysis instrument was developed (Table 2) based on a previous relevant study (Besemer and Treffinger, 1981). The AI products were scored on three aspects: novelty, resolution, and elaboration and synthesis.

"Novelty" refers to the extent of the product's "newness." In other words, how many and how extensively new processes, new techniques, new materials, and new concepts were used in developing the product; how new the product is both inside and outside its expected application field; and how it affects the development of future creative products. The novelty aspect included two specific factors: originality and surprise.

"Resolution" represents the degree to which the product fits or meets the needs of the problematic situation. This aspect consists of four factors: value, logicalness, usefulness, and comprehensibility.

"Elaboration and synthesis" refer to the extent to which disparate elements are combined into a refined, developed, coherent, and whole statement or unit, embodying organic qualities, elegance, and craftedness.

Two researchers assessed the groups' products independently and then calculated the average scores, resulting in the final score for each group (Table 3).

3.3.4 Data analysis. To answer the first study question on how metadiscourse was adopted in participants groups' knowledge building discourse, all notes (N = 541) during the 12 weeks were coded by two researchers using the coding scheme described in Section 3.3.1. They discussed the disparities in their understanding and eventually agreed on each note. Then, the average agreement was calculated with the Kappa coefficient (Kappa = 0.861 > 0.750), indicating good coding consistency.

To answer the second study question regarding how metadiscourse promotes the development of progressive discourse, an epistemic network analysis (ENA; Shaffer *et al.*, 2016) was employed. ENA was designed to model the connection structure among coded elements (e.g. knowledge, skills, and other cognitive elements) and visualise them in the dynamic network model. In the models, the co-occurrence of codes within defined data segments is quantified to illustrate the structure and strength of the connections. Notably, the nature of the most salient connections in the models could be represented by the position of its centroid (Shaffer *et al.*, 2016; Shaffer and Ruis, 2017).

To plot the centroid of six groups, we used the *group* as an analysis unit and defined the *activity* (i.e. "theme choosing" and "functions designing") as stanzas to conduct ENA based on the above coding results. Then, a mean network could be displayed to explore the relationships between progressive discourse and metadiscourse. Finally, a connection

Table 1. A coding scheme of discourse in knowledge building communities

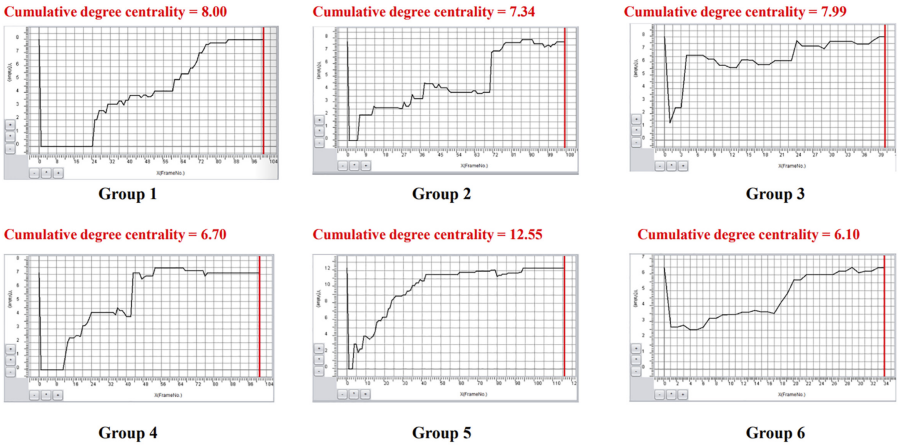
Category	Subcategory	Description	Examples
Metadiscourse (Whitebread *et al.*, 2009; Ouyang *et al.*, 2022; Zhu *et al.*, 2022)	Setting group goals (SG)	Group members consider the requirement of knowledge building tasks and set specific and feasible group goals through discussion	"Our goal is to design an intelligent lost-and-found system that will help staff and students to recover lost and found items efficiently and improve the quality of campus life to some extent."
	Making group plans (MP)	Group members first consider the goals of knowledge building tasks and then make feasible group plans through discussion, such as allocating the time slots and subtasks as well as assigning roles for members	"In order to better achieve the objectives of the mission, we should first conduct an extensive literature study and then express our different opinions through KF [Knowledge Forum]."
	Reviewing the state of knowledge building progress (RP) (Zhao and Chan, 2014)	Group members review their progress through discussion, e.g. how is the group going? What are the problems and difficulties the group is experiencing during the progress of knowledge building?	"We are now discussing the content of the following: a card to borrow classrooms, that is, the use of a card to open the study room and the borrowed classroom and a card applet, real-time view of the status of study room uses, booking collocation study room open, borrowing classroom application function."
	Reflecting on ideas development (RD)	Group members reflect on the ideas development trajectory, i.e. the growth of and gaps in ideas, and discuss which instructions should be taken to promote ideas development	"Next, we need to consider what are the elements of the lost and found process. Does Lost and Found need to be online? What kind of lost and found mechanism is in place? What is the functional design of the online Lost and Found platform?"
	Coordinating group efforts (CE)	Group members spontaneously (and collectively) take responsibility for regulating and coordinating the group's efforts to create a positive environment for achieving the goals of knowledge building	"We need to look for more literature to verify that the technology to be used to identify the number of people is achievable and to explore the technology more closely."
	Inviting participation (IP)	Monitor the state of the community (group members) and invite learners to participate and contribute more to knowledge building	"If you have any comments on my ideas, please feel free to build-on."
	Commenting on ideas (CI)	Group members comment on each idea's contribution to group knowledge development	"It's a good idea to use card machines to keep lost campus cards in one place and to manage them digitally."
	Evaluating products (EP)	Group members evaluate whether the finished products have achieved the expected or desired outcomes	"Our bookable intelligent floor sweepers are highly feasible because the more popular round sweepers on the market today are easy to buy and more affordable."

(*continued*)

Table 1.

Category	Subcategory	Description	Examples
Progressive discourse (Zhu *et al.*, 2022)	Contributing diverse ideas (CI)	Group members contribute diverse ideas to the knowledge building process	"It is always impossible to get a place in the study room. One person can sit in a row, which is inefficient. Can we set up a reservation system?"
	Advancing ideas (AI)	Group members add new ideas and advance the discussion to a higher level	"Electronic screens can be installed underneath a classroom to scroll the usage of each classroom (in class, empty, borrowed) and to display the number of empty classrooms in real-time (install sensor devices in classrooms to display the number of people in real-time like a tourist attraction), then people can choose empty classrooms for self-study according to the number of empty classrooms."
	Achieving shared understanding or goals (AG)	Discuss or adjust group goals if peers raise new questions, considerations, or concerns	"After discussion, artificial intelligence monitoring is responsible for the headcount function, and card swiping machine is responsible for the check-in function of the group." "The card swipe machine is set up at the entrance of the classroom, and those who participate in the group need to swipe their cards and sign in within the specified time; otherwise, reputation points will be deducted."
	Rise above (RV)	Rive above individual ideas to achieve new syntheses	"The main points we discussed included: 1) Campus-related issues; 2) Education-related issues; 3) Elderly medical needs issues; 4) Internet + shopping issues; and 5) Urban sanitation problems."

Source(s): Table by authors



Source(s): Figure by authors

Figure 1.
The cumulative degree centrality (CDC) of six groups

coefficient was used to determine the most sophisticated and prominent features among different types of discourse (i.e. metadiscourse and progressive discourse).

To answer the third study question regarding relationships among the different types of metadiscourse and group knowledge advancement and artifacts, we conducted two different Chi-square (χ^2) tests. In the first Chi-square test (2*8), the three groups with the highest cumulative degree centrality were viewed as the productive groups (i.e. $CDC_{G1} = 8.00$, $CDC_{G3} = 7.99$ and $CDC_{G5} = 12.55$), while other groups were regarded as unproductive groups (i.e. $CDC_{G2} = 7.34$, $CDC_{G4} = 6.70$ and $CDC_{G6} = 6.10$) (*Note.* The above two categorical variables were represented in columns). Then, the eight subcategories of metadiscourse were represented in rows. In the second Chi-square test (2*8), the groups were classified into high-performance (G1 = 90, G3 = 89 and G4 = 94) and low-performance groups (G2 = 88, G5 = 87 and G6 = 84) based on the mean ratings (Mean = 88.67) of groups' artifacts. Similarly, the two categories of performance were represented in columns, while the subcategories of metadiscourse were represented in rows. Finally, we used *z*-tests and adjusted standardised residuals (Field, 2013) to examine the role of different types of metadiscourse in group knowledge advancement and group artifacts.

4. Results

4.1 Types of metadiscourse manifested in groups

Table 4 shows the extent to which each of the six groups used the different types of metadiscourse and progressive discourse. Of all the discourse in the KF community, metadiscourse accounted for 42.64%, 14.29%, 49.72%, 39.42%, 36.92%, and 21.15%, respectively, among the six groups. These results show that progressive discourse was the primary form of discourse, and metadiscourse should be fostered and scaffolded in future studies.

Across all six groups, the types of metadiscourse with the highest frequency of student adoption were RD (N = 96) and CI (N = 105), while SG (N = 12) and MP (N = 24) were the least frequently adopted. This finding indicates that most group members could monitor and evaluate the state of knowledge development in the knowledge building community to continuously improve their ideas. However, the groups may lack awareness of setting specific goals and making feasible plans before finishing tasks.

Criteria		Description	Weight
Novelty (30%)	Originality	The product is unusual or infrequently seen in a universe of products made by people with similar experience and training	15%
	Surprise	The product has outstanding characteristics (such as shapes and functions) that can exceed people's expectations	15%
Resolution (40%)	Value	The product fits and answers enough of the needs of the problematic situation	10%
	Logicalness	The product or solution follows the accepted and understood rules for the discipline	10%
	Usefulness	The product is judged worthy by users, listeners, or viewers because it fills a financial, physical, social, or psychological need	10%
	Comprehensibility	The product has clear and practical applications	10%
Elaboration and synthesis (30%)	Organic qualities	The product has a sense of wholeness or completeness about it	10%
	Elegance	The product is expressed in a refined, understated way	10%
	Craftedness	The product has been worked and reworked with care to develop it to its highest possible level for that point in time	10%

Table 2.
The rubric of groups' artifacts

Source(s): Table by authors

	Novelty	Resolution	Elaboration and synthesis	Final scores
Group 1	27	38	27	90
	26	36	26	
Group 2	26	36	26	88
	27	37	24	
Group 3	28	37	28	89
	25	35	25	
Group 4	28	38	28	94
	29	38	27	
Group 5	26	37	25	87
	25	36	25	
Group 6	24	35	25	84
	25	34	25	

Table 3.
The final scores of six groups' artifacts

Note(s): The total score of group artifacts was 100
Source(s): Table by authors

In terms of progressive discourse, students are more inclined to express their own opinions, such as using CI (N = 226) and AI (N = 350), but they lack synthesis and summaries of individual ideas.

4.2 Examining the role of metadiscourse in progressive discourse

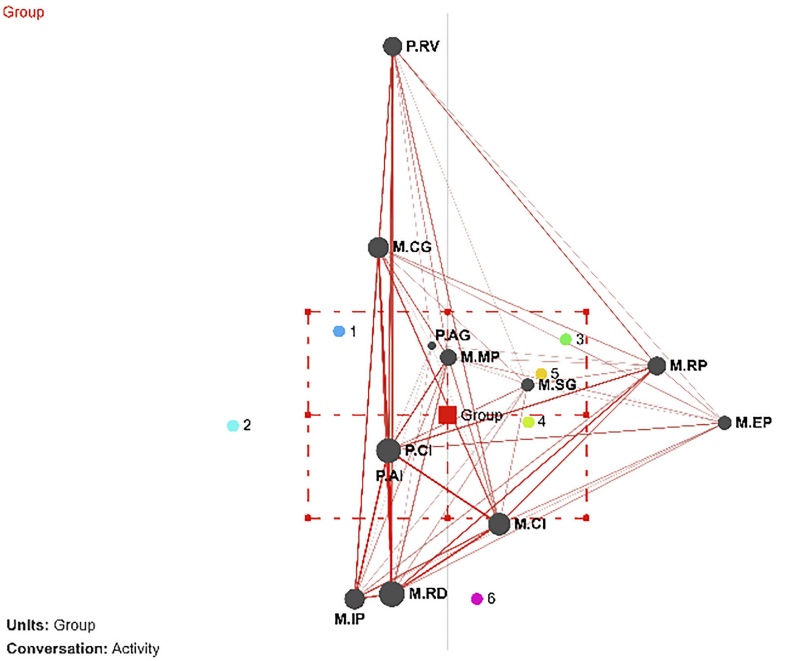
Figure 2 illustrates the connections among different types of metadiscourse and progressive discourse by plotting points from the ENA. The mean centroid of six points is shown as a red square with a 95% confidence interval for each dimension (represented by the rectangular outline). Only connection coefficients above 0.1 are shown in Table 5 to determine salient characteristics among them.

Table 4. The extent to which different types of discourse were used by each group

Groups (numbers and proportion of notes)	Metadiscourse						Progressive discourse						Numerical and percentage amount of metadiscourse compared to all discourse
	SG	MP	RP	RD	CE	IP	CI	EP	CI	AI	AG	RA	
G1	2 (0.75%)	8 (3.02%)	12 (4.53%)	36 (13.58%)	12 (4.53%)	8 (3.02%)	35 (13.21%)	0 (0.00%)	67 (25.28%)	80 (30.19%)	1 (0.38%)	4 (1.51%)	113 (42.64%)
G2	0 (0.00%)	2 (2.38%)	0 (0.00%)	7 (8.33%)	1 (1.19%)	1 (1.19%)	1 (1.19%)	0 (0.00%)	31 (36.90%)	39 (46.43%)	0 (0.00%)	2 (2.38%)	12 (14.29%)
G3	2 (1.12%)	7 (3.91%)	10 (5.59%)	33 (18.44%)	8 (4.47%)	7 (3.91%)	20 (11.17%)	2 (1.12%)	21 (11.73%)	64 (35.75%)	1 (0.56%)	4 (2.23%)	89 (49.72%)
G4	3 (2.88%)	3 (2.88%)	8 (7.69%)	3 (2.88%)	9 (8.65%)	2 (1.92%)	10 (9.62%)	3 (2.88%)	22 (21.15%)	40 (38.46%)	0 (0.00%)	1 (0.96%)	41 (39.42%)
G5	4 (1.87%)	1 (0.47%)	4 (1.87%)	15 (7.01%)	6 (2.80%)	3 (1.40%)	35 (16.36%)	11 (5.14%)	49 (22.90%)	83 (38.79%)	0 (0.00%)	3 (1.40%)	79 (36.92%)
G6	1 (0.96%)	3 (2.88%)	2 (1.92%)	2 (1.92%)	3 (2.88%)	6 (5.77%)	4 (3.85%)	1 (0.96%)	36 (34.62%)	44 (42.31%)	1 (0.96%)	1 (0.96%)	22 (21.15%)
Total	12 (1.26%)	24 (2.53%)	36 (3.79%)	96 (10.11%)	39 (4.11%)	27 (2.84%)	105 (11.05%)	17 (1.79%)	226 (23.79%)	350 (36.84%)	3 (0.32%)	15 (1.58%)	356 (37.47%)

Note(s): SG=Setting group goals, MP = Making group plans, RP=Reviewing the state of Knowledge Building progress, RD = Reflecting on ideas development, CE=Coordinating the group efforts, IP=Inviting participation, CI=Commenting on ideas, EP = Evaluating products, CI=Contributing diverse ideas, AI = Advancing ideas, AG = Achieving shared understanding or goals, RA = Rise above

Source(s): Table by authors



Source(s): Figure by authors

Figure 2.
The mean network of six groups

Correlations	Connection coefficient
M.MP-P.CI; M. MP-P.AI	0.12; 0.12
M.RP-P.CI; M. RP-P.AI; M.RP-P.RV	0.12; 0.12; 0.11
M.RD-P.CI; M. RD-P.AI; M. RD-P.RV	0.21; 0.21; 0.15
M.CE-P.CI; M. CE-P.AI; M. CE-P.RV	0.15; 0.15; 0.12
M.IP-P.CI; M. IP-P.AI; M. IP-P.RV	0.16; 0.16; 0.12
M.CI-P.CI; M. CI-P.AI; M. CI-P.RV	0.17; 0.17; 0.11

Note(s): M = Metadiscourse; P= Progressive discourse
M.MP = Making group plans; M.RP=Reviewing the state of Knowledge Building progress; M. RD = Reflecting on ideas development; M. CE=Coordinating the group efforts; M. IP=Inviting participation, M.CI=Commenting on ideas
P.CI=Contributing diverse ideas; P.AI = Advancing ideas; P.RA = Rise above
Source(s): Table by authors

Table 5.
Connection coefficient of the different types of metadiscourse and progressive discourse

From Figure 2 and Table 5, it is clear that most types of metadiscourse correlated with progressive discourse, with 17 relationships identified between them. Remarkably, the metadiscourse types were mainly associated with P.CI, P.AI, and P.RV. As for the strength of these correlations, M. RD and M. CI were more strongly correlated (i.e. thicker lines) with progressive discourse compared to other types of metadiscourse. For example, M. RD was more closely correlated with P.CI than M. CE with P.CI (with connection coefficients of 0.21 and 0.15, respectively). In contrast, weaker correlations (i.e. thinner lines) between M. RP (or M. CI) and P.RV were detected by the connection coefficients (0.11).

4.3 Examining the role of metadiscourse from knowledge advancement and group artifacts

As shown in Table 6, overall, the results of two Chi-square tests indicated there were significant relationships between metadiscourse and knowledge advancement ($\chi^2 = 18.065$, $p = 0.010$, 99% CI [0.007, 0.012]) and group artifacts ($\chi^2 = 20.644$, $p = 0.003$, 99% CI [0.002, 0.005]), respectively.

For knowledge advancement, post hoc analysis was carried out using a z-test (Bonferroni method). This test indicated that the RD, CI, and CE types of metadiscourse were used significantly more by the productive groups than the nonproductive groups (*Note.* the clarifications contained in the table subscripts are different for the columns for RP, CI, and CE). This result could also be verified using adjusted standardised residuals. From standard residuals, we found that when groups used more RD ($z = 2.40, p < 0.05$), CI ($z = 2.00, p < 0.05$), and CE ($z = 2.00$, $p < 0.05$) than expected, they were more likely to achieve productive knowledge advancement.

Considering the group artifacts, we similarly saw from the z-tests that the high-performance groups adopted significantly more RP than the low-performance groups. Adjusted standardised residuals also indicated that the more groups used RP ($z = 2.00$, $p < 0.05$) than expected in knowledge building, the more likely they would create high-quality artifacts.

5. Discussion

5.1 Fine-grained level: the emergence of the different types of metadiscourse and their role in progressive discourse

For the first study question, we found that RD and CI were the metadiscourse types most frequently adopted by students, whereas SG and MP were less frequently adopted. This result can be explained by considering teacher interventions and technology.

Knowledge Advancement	Column PG	Column N-PG	*p*-value Fisher's exact test (2-sided)	Group artifacts	Column HG	Column LG	*p*-value Fisher's exact test (2-sided)
SG	8_a	4_a	0.010	SG	7_a	5_a	0.003
MP	16_a	8_a		MP	18_a	6_a	
RP	26_a	10_a		RP	30_a	6_b	
RD	84_a	12_b		RD	72_a	24_a	
CE	26_a	13_b		CE	29_a	10_a	
IP	18_a	9_a		IP	17_a	10_a	
CI	90_a	15_b		CI	65_a	40_a	
EP	13_a	4_a		EP	5_a	12_b	

Note(s): PG= Productive groups; N-PG= Non-productive groups; HG= High-performance groups; LG = Low-performance groups

SG=Setting group goals; MP = Making group plans; RP=Reviewing the state of Knowledge Building progress; RD = Reflecting on ideas development; CE=Coordinating the group efforts; IP=Inviting participation, CI=Commenting on ideas; EP = Evaluating products

a. In the first Chi-square test, 2 cells (12.5%) have an expected count less than 5, and the minimum expected count is 2.53; In the second Chi-square test, 1 cell (6.3%) have an expected count less than 5, and the minimum expected count is 3.81

b. Using a Z-test to compare the column proportions. If a pair of values is significantly different, the values have different subscript letters assigned to them

c. In the first Chi-square test, the standardised statistic is −1.456; In the second Chi-square test, the standardised statistic is 3.158

Source(s): Table by authors

Table 6. Results of two Chi-square tests using Fisher's Exact Test (FET)

Regarding teacher interventions, community culture impacts the type of metadiscourse used by members in the knowledge building community (Zhao and Chan, 2014). In this study, the teacher required students to conduct weekly collective reflections. For example, the students needed to select at least five notes written by community members, analyse their strengths and weaknesses, and then write comments describing how and why these notes contributed to the sustainable development of ideas. This requirement led students to participate more in monitoring ideas' development trajectory and evaluating their quality and utility.

Consistent with our findings, previous research found that developing collaborative metacognitive culture helped students to engage in continuous assessment and reflection to regulate and improve their ideas (Lin and Chan, 2018; Hong *et al.*, 2019a, b; Yang *et al.*, 2020a). However, students usually do not have the awareness to reflect on and regulate their collective idea development without teacher interventions (Ouyang *et al.*, 2022).

Previous studies demonstrated that a greater sense of community identification is the antecedent that supports an individual's knowledge building behaviours (Deng *et al.*, 2019; Deng and Guo, 2021; Zhang *et al.*, 2023). A sense of community identification refers to students' sense of belonging to their own knowledge building communities, the belief that they are part of them, and the desire to contribute to them. Having a strong sense of community identification enables a group to collaborate more frequently and exchange ideas more readily (Chang *et al.*, 2018). Thus, to address the above problem, cultivating a sense of community identification might help foster a collaborative metacognitive culture (Yang *et al.*, 2020a). According to this culture, the group members reflect, regulate, and build upon ideas together. Every individual's contribution is vital to the community, and each idea can be improved progressively.

KF, as an essential technical factor, may also influence the frequency at which different types of metadiscourse are used. Some scaffolds embedded in KF can support idea-driven and theory-building metadiscourses (e.g. "A better theory," "I need to understand," and "The main points of our discussion are . . ."). Moreover, reflective assessment tools in KF, such as Idea Thread Mapper and authorNetwork, have been shown to be effective in helping students assess their online discussion data (Yang *et al.*, 2020b). Consequently, the students progressively improved their knowledge building and developed a deep domain understanding through continually reflecting and commenting on ideas development.

These results are consistent with the findings of Lee *et al.* (2006) and Hong *et al.* (2011), who showed that KF is a beneficial environment for students to advance their ideas using embedded scaffolds and reflective assessment tools. Additionally, this study, in line with activity theory (Vygotsky, 1986), demonstrates that collaborative tools are not merely external influencing factors; instead, they are involved in the production and regulation of ideas, thereby mediating knowledge building processes (Kanke, 2021).

However, there is less support or scaffolding for setting goals and making plans in knowledge building. Plus, students are usually unaware of setting goals and making plans (Zheng *et al.*, 2017). A more likely explanation is that students lack the intention to externalise their implicit awareness of task goals and plans into explicit actions. Students subconsciously set a goal for the task and plan how to accomplish it, but they do not express it verbally. Some students even resent teachers' attempts to make them set goals and make plans. A combination of environmental and personal factors hinders an individual's adoption of SG and MP.

This result corroborated the findings of a previous study, which reported that students had difficulty setting goals and making plans in communities, resulting in less usage. Specifically, there is an interplay between environmental and personal factors in accomplishing shared goals and plans, which require students to access up-to-date information regarding shared tasks as well as each group member's goals and planning perceptions (Hadwin *et al.*, 2018; Zheng *et al.*, 2019).

But goal setting and planning strategy, as one of the critical elements of self-regulated learning (Zimmerman and Pons, 1986), has its most significant positive impact on task performance (Earley *et al.*, 1990). Knowing goals and making plans is necessary to help learners stay on track toward sustained knowledge. In fact, according to Boekaerts and Corno (2005), students' adopted learning goals and plans steer the whole knowledge building process. During this process, they identify goals and formulate plans for extending knowledge and sustaining motivation, as well as deliberate on small-grain tactics and overall strategies, making decisions regarding which one will support progress toward chosen goals (Winne, 1995).

Therefore, instructors and relevant platforms should provide scaffolds, hints, prompts, or other interventions for setting goals and making plans to engage learners in group metacognitive activities and develop their autonomy in future knowledge building environments (Chai and Zhu, 2021).

For the second study question, we found that most metadiscourse types correlate with progressive discourse. This result can be interpreted based on the Progressive Knowledge Building Inquiry Model (White and Frederiksen, 1998; So *et al.*, 2010). This model includes four main cycle phases: *idea generation*, *idea connection*, *idea improvement*, and *rise above*. During these phases, students mainly use the four progressive discourse subcategories of contributing diverse ideas, advancing ideas, achieving shared understanding or goals, and rising above. Furthermore, throughout the inquiry cycle, metacognitive reflective thinking is continuously enacted to encourage students to reflect on the knowledge building process.

Metadiscourse, as the medium of metacognitive reflective thinking, is involved in this process as a way to review two perspectives on progress: progress of the work process and progress on creating the products (White and Frederiksen, 1998). In this study, students mainly adopted the metadiscourse types RD, CI, RP, and EP to reflect on the above progress. The first two types of metadiscourse aim to reflect the progress of ideas (i.e. ideas-centred), while the remaining two contribute to the progress of artifacts (i.e. artifacts-centred). Furthermore, this process should be social, requiring participants to coordinate group efforts (CE) and invite participation (IP). These social metadiscourses could be regarded as facilitators to support collective knowledge building (i.e. group-centred).

Lastly, the ultimate goal of knowledge building is the completion of predetermined tasks, thus requiring students to set task goals (SG) and make task plans (MP) (i.e. tasks-centred). Above all, as proposed in Figure 3, this process can be divided into four phases, in which four types of metadiscourse and progressive discourse are intertwined together to promote collective knowledge advancement and finally to improve group performance.

This inquiry process adheres to the findings of Kanke (2021), which indicated that activities of knowledge curation work in WikiProject discussion pages (i.e. a broader collaborative knowledge building community) also fall into two categories: process-related and infrastructure-related. It is the process-related activities, such as conceptualising, creating, selecting, and ingesting, that contribute to populating Wikidata with external data, which corresponds to our study's progressive discourse. Due to the socially shared regulation nature of the curation lifecycle, several infrastructure-related activities are more prevalent, including "determining the scope of a project" and "dividing the discussion into manageable sections," which is consistent with our study's metadiscourse.

Generally, the activities identified in knowledge curation fall into two categories: those related to knowledge construction and those related to regulation and monitoring. The two activities are not in parallel. Instead, they are intertwined and work together to create knowledge. The discussion threads in our study, however, revealed relatively few norms and rules compared to Kanke's study (2021) in WikiProject. A possible reason for this inconsistency may be that it emphasises a student-driven and open-ended inquiry process within the context of a collective knowledge building community without extensive teacher

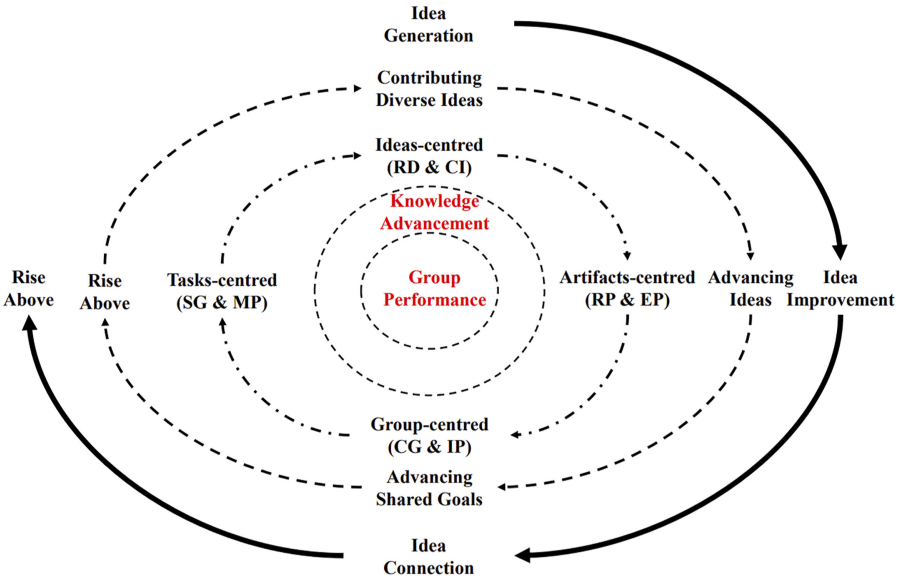


Figure 3.
Progressive knowledge building inquiry model

Source(s): Figure by authors

prescription and guidance. Nevertheless, it is not to be construed that the activities (e.g. norms and rules) do not occur; rather, they are not discussed in our study. In future research, it is recommended to examine the impact of norms and rules on collective knowledge building (Li *et al.*, 2023).

ENA also revealed that RD and CI had stronger correlations with progressive discourse. This finding suggests most students use these kinds of patterns to promote collective inquiry. Specifically, they first comment on other members' ideas and then present their own (M. CI-P.AI/P.CI). Alternatively, they initially reflect on the ideas' development trajectory and give directions for facilitating discussion, thus stimulating other group members to present new ideas (M. RD- P.AI/P.CI).

This result is consistent with previous research (Chen *et al.*, 2015; Lin *et al.*, 2018; Liu *et al.*, 2023a, b), which showed that a student assesses ideas or directions of inquiry as promising and leads to subsequent ideas' contribution, revision, or integration. As a result of highlighting promising ideas and directions, students' attention is also brought to new ideas emerging in the community, leading students to work with ideas collectively.

This finding further supports the Digital Curation Centre's (DCC) Curation Lifecycle Model (Digital Curation Centre, 2019), in which the general data lifecycle includes conceptualising, evaluating, and ingesting data from external sources. Transforming tacit knowledge into explicit knowledge generally involves stages of presentation, evaluation, and internalisation of ideas. Other inquiry sequences are also used in knowledge building threads, such as M. IP- P. AI/P. CI/P. RV. Specifically, students actively invite others to promote the knowledge building process. This result indicates that the knowledge building process may be facilitated by learners constructing their own knowledge and meaning and inviting others to participate in maintaining a balanced and connected social network (Wang *et al.*, 2023). In this way, by establishing a balanced network, everyone can participate in knowledge building activities, thus promoting the long-term growth and health of the community (Deng and Guo, 2021).

5.2 Coarse-grained level: role of different types of metadiscourse in groups' knowledge advancement and artifacts

For the third study question, our results indicate that RD, CI, and CE are essential in knowledge advancement. As mentioned in question 2, our findings highlight the impact of judging promising ideas or directions on knowledge advancement (e.g. "Are the ideas feasible?", "I think it is a good idea.", and "Do we need any tools to implement this idea?"). It suggests the positive impacts of reflecting on how the working progress (i.e. RD and CI) shapes collective knowledge advancement during knowledge building (Hong and Scardamalia, 2014; Gutiérrez-Braojos *et al.*, 2022).

Previously, studies indicated that metacognitive engagement strengthened students' epistemic agency (Bereiter *et al.*, 2019). During knowledge building inquiries, students who are more engaged in collectively reflecting on, monitoring, and regulating their collective inquiry are more likely to engage in higher-level cognition and emotions (Yang *et al.*, 2022a, b), thereby directing their inquiry, deepening their discourse, and fostering intentional advancement of their community's knowledge (Tao and Zhang, 2018). Furthermore, Chan *et al.* (2019) showed that students who possess deeper metaknowledge are more likely to engage in productive knowledge building inquiries and discussions than those without such knowledge. This finding thus has important implications for practitioners and researchers engaged in developing reflective learning environments to promote student inquiry, engagement, agency, and learning.

Members of productive groups were also more aware of both their individual and others' roles, and they better coordinated their efforts than members of nonproductive groups. This finding echoes our understanding that an individual's awareness of what and how group members contribute to a joint task may positively affect the team's collaborative actions and their overall knowledge advancement (Jiang *et al.*, 2019; Zhang *et al.*, 2023). More specifically, to better promote knowledge advancement, students are not only able to identify their own contributions but are also able to coordinate the contributions of their team members.

As for group artifacts, our findings showed that RP was closely associated with group artifacts. The main reason is that this course requires students to submit conceptualised artifacts related to AI that do not require them to be implemented explicitly. More information gathered about the artifacts will result in less uncertainty about their formation, resulting in improved performance, such as novelty and usefulness (Schöggl *et al.*, 2017). Thus, by checking the progress frequently, students can identify whether there is off-topic information, encouraging them to accumulate more information related to the topic and improving their artifacts.

This result is consistent with Chai and Zhu's study (2021), which found that high-performance groups were more likely to evaluate their knowledge progress than medium- and low-performing groups. Given that, students are advised to frequently reflect on their knowledge progress (e.g. "Are we making progress?", "Are we overlooking something important?", and "What is settled and what is still an open question?") (Tong and Chan, 2020; Darmawansah *et al.*, 2022), and to take a comprehensive view to monitor their community discourse to better locate and adjust their group work.

Moreover, in the future, researchers are recommended to use real-time learning analytics to capture and make available the latest advances to students, which will help them improve their collaborative learning performance (Zheng *et al.*, 2022).

6. Implications and limitations

Significant theoretical and practical implications for knowledge building design and implementation can be drawn from this study.

Theoretically, this study developed a coding framework to detect detailed indicators of metadiscourse; it then analysed the emergence of different types of metadiscourse in

students' knowledge building discourse, contributing to the literature in this field. Additionally, the constructed Progressive Knowledge Building Inquiry Model is useful for examining the role of different metadiscourse types, providing a more detailed representation of collaborative knowledge building inquiry.

Practically, our findings can direct the design of research that intends to advance knowledge and enhance artifacts. Practitioners can use it, for example, to develop suitable plans and scaffolding to nurture an open knowledge environment. Additionally, a deeper comprehension of the role of metadiscourse can provide implications concerning regulating the community and promoting sustained knowledge and learner agency.

Admittedly, this study has several limitations. First, data were collected from a single case. Because our data were drawn from one course at one university in China, our sample size is limited. The results may not be generalisable to different universities, contexts, or subjects. However, as an exploratory case study, our study does not focus on the individual student level but on the discourse level. Thus, our sample size (N = 541) is enough from this perspective (e.g. Ouyang *et al.*, 2021; Zhu *et al.*, 2021; Liu *et al.*, 2023a, b). Additionally, we also collected process and summative data from multiple dimensions to improve our study's granularity, including notes and students' final group artifacts. This approach can to some extent reduce the negative impact of a small sample size on the results of our study (Hoppe, 2017). Future research should aim to increase the sample size and extend the focus to other educational levels and subjects to improve the generalisability of the study.

Second, the group members' use of metadiscourse might not have been adequately captured in the KF environment. Some discussions about planning, monitoring, and evaluating group tasks may have taken place only face-to-face. To better understand how metadiscourse manifests itself, future studies should consider capturing students' online and offline knowledge building discourse more comprehensively.

Third, the relationship between different types of metadiscourse and progressive discourse and knowledge advancement (or group artifacts) cannot be revealed as this study, an ex-post-facto design, does not have a control group (Ary *et al.*, 2018). The use of ex-post-facto research design, nevertheless, is commonly applied in educational research (e.g. Lavonen and Lavonen, 2000; Emepue and Soyibo, 2009) for situations where researchers have no control over what existed in schools. Despite the limitation, the correlation is still worth noting.

Moreover, teachers' discourse may also influence the process of inquiry. Thus, future studies need to investigate the effect of teachers' metadiscourse on students' knowledge building patterns using a quasi-experimental research design. Furthermore, comparing the characteristics of epistemic networks of metadiscourse and progressive discourse between different course stages could also provide valuable insights.

7. Conclusion

In this study, we first identified detailed indicators of metadiscourse and developed a framework for analysing them within knowledge building discourse. Then, we examined the role of different types of metadiscourse from both a fine-grained and coarse-grained level.

On the fine-grained level, this study explored the emergence of metadiscourse in participants' groups and the correlations between metadiscourse and progressive discourse. Our study found that RD and CI were most frequently adopted by students when teachers and technology were involved. Fewer scaffoldings, prompts, or other interventions were used to support students in setting goals and making plans, which should entice the attention of relevant stakeholders. In knowledge building discourse, we identified four metadiscourse types—tasks-centred, ideas-centred, artifacts-centred, and group-centred—all of which interact with progressive discourse to create knowledge, where the general process of knowledge building entails proposing ideas, assessing them, and advancing them.

The coarse-grained level aimed to investigate the role of different types of metadiscourse in knowledge advancement and group artifacts. The findings suggest that efficient knowledge advancement necessitates students assuming dual roles: first, reflecting on and evaluating the development of ideas; and second, understanding their individual roles within a team and coordinating their efforts with other members. Complementarily, the study also unveiled a positive correlation between artifact-centred discourse (i.e. RP) and product performance. This result underscores the potential benefits of continuously monitoring a product's progress to enhance its overall performance.

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