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Developing metadiscourse through reflective assessment in knowledge building environments

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ABSTRACT

This study examined how reflective assessment supported by principles facilitated metadiscourse for knowledge advances mediated by Knowledge Forum® (KF). Participants were 60 tertiary students in two classes engaging in knowledge building and reflecting on their collaborative knowledge building using e-portfolios; one class was a principle-based knowledge-building environment (KBP, n = 30), and the other a regular knowledge-building environment (KBR, n = 30). The KF embedded assessment tools, the Analytical Toolkit and Applet, showed increased KF participation and connectedness during the year. Regression analysis showed that KF participation predicted conceptual understanding for both classes. Analyses of e-portfolios revealed that the students adopted nine reflective strategies in knowledge building, and that reflective metadiscourse strategies involving metacognitive and collective processes were related with deeper conceptual understanding. Analyses of online discourse threads further showed that metadiscourse involving collective processes was associated with higher levels of knowledge advances. Both classes showed improvement and the KBP class outperformed the KBR class on KF participation, metadiscourse processes and conceptual understanding. This study has theoretical implications advancing the idea of metadiscourse, *discourse about discourse*, for enriching research on knowledge building and computer-supported collaborative learning (CSCL). There are also design implications for using principle-based e-portfolios to facilitate collective reflection and metadiscourse to address issues of fragmented online discussion, and for promoting sustained inquiry.

1. Introduction

Helping students to work with ideas creatively, to engage in productive discourse, and to reflect on learning and inquiry, supported by technology, are important educational processes in the knowledge-based era. Computer-supported collaborative learning (CSCL) is a major research field that examines how learning and knowledge building emerge via collaboration and discourse mediated by technology (Stahl & Hesse, 2011; Stahl, Koschmann, & Suthers, 2014). CSCL in higher education is increasingly widespread (Goodyear, Jones, & Thompson, 2014; Strijbos, Kirschner, & Martens, 2004) and online discussion forums are commonly employed to promote collaborative learning through inquiry and discourse (Ellis & Goodyear, 2010; Hew & Cheung, 2012a; Loncar, Barrett, & Liu, 2014). The goal of this paper is to examine metadiscourse processes, students' inquiry and reflection about their

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discourse, that promote online discussion and knowledge advances situated in a knowledge-building environment.

Despite the increased popularity of online forums, student discussion threads are often short, fragmented, and incoherent (Calvani, Fini, Molino, & Ranieri, 2010; Hew & Cheung, 2012b, pp. 31–48; Hewitt, 2005; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003); sustained inquiry is often non-existent, and putting students together does not usually bring about productive interactions or collaboration (Damşa, 2014; Kreijns, Kirschner, & Jochems, 2003). Different approaches have been used to scaffold collaboration and productive discourse including peer facilitation (Hew & Cheung, 2008), scripting (Fischer, Kollar, Stegmann, Wecker, & Zottmann, 2013), and role-taking (Cesareni, Cacciamani, & Fujita, 2016; Hou, 2011) usually focusing on task performance. This paper examines reflective assessment with students taking agency in assessing their own collaboration in promoting knowledge advances. Research on assessment and analysis of online collective discourse in CSCL (Puntambekar, Erkens, & Hmelo-Silver, 2010) generally focuses on researchers assessing interactions, rather than students taking agency in assessing their own collaboration. While research has examined students' active roles such as peer assessment in online learning (Tenório, Bittencourt, Isotani, & Silva, 2016), the emphasis has been on individual learning and outcomes rather than collective knowledge and community advance. Designing student-directed assessment approaches and analyzing the metadiscourse processes that promote online learning and collaborative knowledge building merits further investigation.

This paper is premised on the knowledge-building model, mediated by Knowledge Forum® (KF), which focuses on students' collective responsibility for sustained idea improvement (Scardamalia & Bereiter, 2006, 2014). Research in knowledge building has used portfolios for assessment (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007), and has employed learning journeys, similar to portfolios, to promote knowledge advances (Zhang et al., 2018). Researchers have also examined reflective assessment via e-portfolios to characterize and foster productive online discourse (Lee, Chan, & van Aalst, 2006; Yang, Aalst, Chan, & Tian, 2016). In this paper, reflective assessment can be defined as assessment undertaken by students in transforming their knowledge; it includes *metacognitive* facets of reflection and *metadiscourse* involving reflection, synthesis and rise-above of knowledge building discourse (Zhang, Tao, Sun, Peebles, & Naqvi, 2015). Although research has demonstrated positive effects of portfolio-based reflective assessment in knowledge advances (van Aalst & Chan, 2007; Yang et al., 2016) and increased attention has been given to metadiscourse (Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015; Zhang et al., 2015), it is not clear what processes are involved in reflective assessment that support knowledge advances; and the nature and role of metadiscourse also remain relatively unexplored. Principle-based pedagogy rather than scripted procedures has been advocated in knowledge building (Hong & Sullivan, 2009; Scardamalia & Bereiter, 2014), and its relationship to reflective assessment also needs examination.

This study is designed to address the issues of promoting productive online inquiry and discourse. We examine how a reflective assessment based design, using e-portfolios in a knowledge-building environment enriched by principles, will promote online discourse, and specifically investigate the nature and role of metadiscourse processes in reflective assessment designs. We first describe the design of reflective assessment in two knowledge building classes, one regular and the other principle-based. In terms of analyses, we first explore students' online participation patterns and changes over time in both classes. Then, we investigate more deeply on students' engagement in e-portfolios, i.e. their reflective strategies and metadiscourse processes. In addition, we also examine metadiscourse processes in their online discourse. Finally, we examine the differences between regular and principle-based knowledge building classes, to illuminate the role of principles in reflective assessment and knowledge building.

2. Theoretical background

2.1. Knowledge building theory, technology and principles

The knowledge-building model postulates the importance of acculturating students into a knowledge-creation culture (Scardamalia & Bereiter, 2006); the key tenet is developing students' collective agency and responsibility for sustained idea improvement (Scardamalia & Bereiter, 2014). In knowledge-building classrooms, students generate problems and questions, pose ideas and build on those of others, co-construct explanations, and deepen and theorize ideas for improvement. As a pioneer model of CSCL, KF has evolved over the years to support students' progressive discourse and idea advancement (Scardamalia & Bereiter, 2014; see review,; Chen & Hong, 2016). KF is a communal space (see Fig. 1) with affordances to support the creation and improvement of ideas for collective advances.

The knowledge-building model originated in western cultures (Hakkarainen, 2003; Hewitt, 2002; Zhang et al., 2007, 2009) was adopted later into eastern contexts (Hong, Chang, & Chai, 2014; Oshima et al., 2006; Lee et al., 2006; So, Seah, & Toh-Heng, 2010; Yang et al., 2016). Research in knowledge building has examined design-based research (Chen & Hong, 2016), socio-cognitive dynamics (e.g., Zhang et al., 2007, 2009) and effects on scientific inquiry (Hakkarainen, 2004; Zhang et al., 2007), conceptual understanding (Hewitt, 2002; Lee et al., 2006), and literacy development (Sun, Zhang, & Scardamalia, 2010).

Increased research interest has now been given to CSCL and knowledge building for tertiary students (Hong et al., 2014). Research has shown how pre-service teachers change their beliefs and relations between sustained knowledge building and epistemic views (Hong, Chen, & Chai, 2016); how KB can support both individual and collective knowledge growth (Zhao & Chan, 2014); and how community and group designs have different effects on students' KB (Siqin, van Aalst, & Chu, 2015). As mainland China university students have been shown to lack interest in collaboration (Ge, 2011), it is of interest to explore how to develop viable designs. Given the importance of assessment in tertiary settings, this paper investigates knowledge building by examining assessment designs for tertiary students.

The idea-centered, principle-based approach is central to knowledge-building pedagogy (Hong & Sullivan, 2009; Scardamalia & Bereiter, 2014); knowledge-building emphasizes principle-based emergent inquiry rather than following classroom routines and

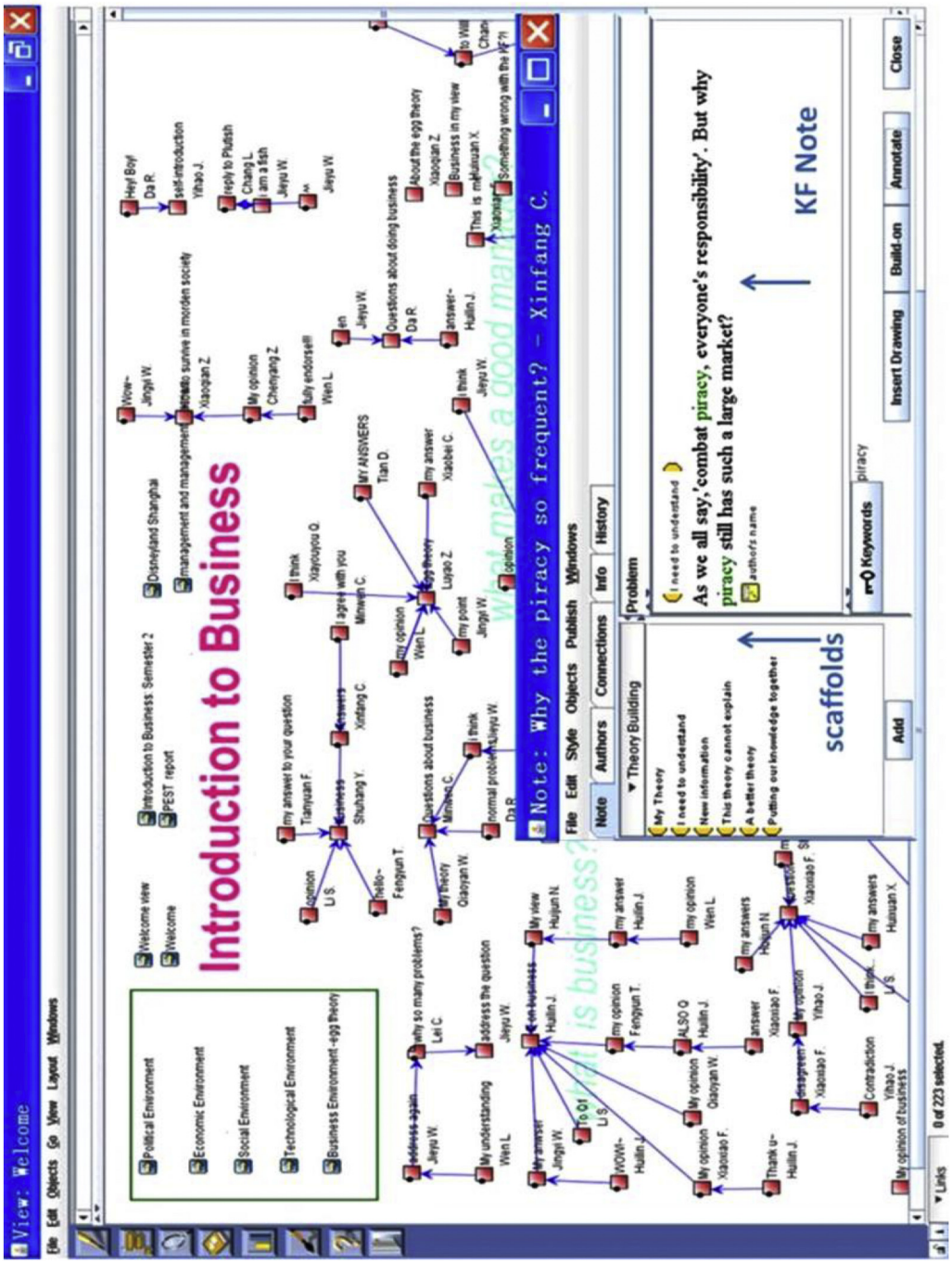

Fig. 1. Knowledge Forum and an example of a KF *Note* and *View*.

scripts for task completion. Scardamalia (2002) postulated a set of 12 knowledge-building principles, for example, “improvable ideas” refers to students viewing ideas as conceptual artefacts that can be improved continually. Zhang, Hong, Scardamalia, Teo, and Morley (2011) described the principle-based approach and its development over eight years in a school, and how teachers' understanding and practices of knowledge building can be advanced supported by principles. Hong et al. (2016) adopted a principle-based pedagogy that facilitated students' collective problem-solving by continually generating, elaborating, and integrating ideas; students developed a more sophisticated epistemic view, conducive to collective knowledge advances.

2.2. Reflective assessment in CSCL and knowledge building

Formative assessment is crucial to student learning (Andrade & Cizek, 2010; Black & Wiliam, 1998), and assessment is transformative (Shepard, 2005). In computer-based learning, web-based assessment facilitates high school students' self-regulated learning (Wang, 2011) and e-learning effectiveness (Wang, 2010), and tertiary students' academic performance (Kleij, Eggen, Timmers, & Veldkamp, 2012). Research in assessment in the cognitive tradition focuses on inquiry and metacognition beyond learning outcomes. Researchers emphasize reflective assessment, focusing on students' reflections on their learning and collaborative processes for metacognition and knowledge construction. White and Frederiksen (1998) pioneered reflective assessment and technology tools to make scientific inquiry accessible to diverse learners, and showed that reflecting on one's learning process and products promotes metacognition and “learning how to learn.” Toth, Suthers, and Lesgold (2002) examined how self and peer assessment using criteria for reflection could enhance students' CSCL inquiry. Etkina, Karelina, Murthy, and Ruibalvillasenor (2009) showed that physics students engaged in design, reflection, and formative assessment advanced their scientific abilities.

Reflective e-portfolio assessment has been utilized to examine and scaffold knowledge advances (Lee et al., 2006; van Aalst & Chan, 2007); students selected exemplar KF notes and submitted *portfolio notes* with a reflective statement explaining how these notes best evidenced knowledge building. Reflective assessment can promote students' conceptual understanding (van Aalst & Chan, 2007) and knowledge advances for different students including low achievers (Yang et al., 2016). By scaffolding students to reflect on and articulate their knowledge progress, reflective assessment characterizes collective knowledge and supports students' conceptual inquiry and domain understanding. However, portfolio assessments were analyzed holistically for the quality of their reflection (van Aalst & Chan, 2007); further research is needed on the dynamics of reflective assessment, and the collective knowledge-building processes it supports.

Research has illustrated different types of discourse, including knowledge sharing, construction, and building (van Aalst, 2009); and has identified key processes of knowledge building including metadiscourse. The key goal of knowledge building is collective advances, and metadiscourse processes involve students' consideration of community aspects, examining their current knowledge progress and setting goals for further inquiry. Zhang, Lee, and Wilde (2012) defined metadiscourse as metacognitive conversations that review the progress of understanding and formulate deeper community inquiry goals. Bereiter and Scardamalia (2016) noted metadiscourse as an important discourse move in productive knowledge building. While metadiscourse is important, it is not common in knowledge-building classrooms (van Aalst, 2009). Recent studies have examined its role in fostering sustained KB (Resendes et al., 2015; Zhang et al., 2015); further investigation and evidence are needed into the roles and dynamics of reflective assessment and metadiscourse in knowledge building in different cultural contexts.

2.3. The present study

This study builds on current knowledge building research, using assessment to promote sustained inquiry and knowledge advances. Previous studies have demonstrated the role of portfolio-based reflective assessment in promoting knowledge advances (van Aalst & Chan, 2007; Yang et al., 2016; Zhang et al., 2007), but have neither used continual portfolio reflections, nor examined the dynamics involved systematically. In addition to investigating students' participation in a CSCL environment, this study integrates the design of reflective assessment and analyses of students' collective reflection processes. Specifically, it examines the metadiscourse processes that support knowledge advances in relation to the quality of conceptual inquiry. Although principle-based design is important (Hong & Sullivan, 2009; Zhang et al., 2011); thus far, there have been few systematic comparative studies. Knowledge building principles provide epistemic goals and standards that help students reflect on their progress; their focus on collective work of metadiscourse can support knowledge advances. This study includes comparisons of two knowledge building classes: one regular and one principle-based. We hypothesize that principle-based pedagogy will help students focus on knowledge-building goals and engage in metadiscourse processes. To summarize, this study involves designing reflective assessment using e-portfolios in knowledge building environments; examines the nature and role of metadiscourse processes; and investigates the role of principles influencing processes and knowledge advances. Three questions are included.

1 What are the patterns of students' KF participation in the designed environment and how are they related to students' conceptual understanding?
2 How do students engage in reflective and metadiscourse processes, and how are these processes related to students' conceptual inquiry and knowledge advances in portfolios and online discourse?
3 What are the differences between the principle-based and non-principle-based environments on students' KF participation, reflective processes, and conceptual understanding?

To address the research questions (RQ), we designed a knowledge-building environment using reflective assessment for two

knowledge building classes, one regular and one augmented with principles. For RQ1, we examined students' participation patterns and investigated the relationship between KF participation and conceptual understanding for both classes. The prediction was that students would show increased contribution and connectedness over time and KF participation would predict conceptual understanding controlling for prior achievement. For RQ2, we conducted qualitative analyses of e-portfolios in both classes to identify reflective strategies/processes, and then did contrastive group analyses of the relationship between those processes and conceptual understanding. We also examined how metadiscourse process was manifested in KF online discourse and its relations to collective understanding. The prediction was that metadiscourse would be associated with higher levels of conceptual inquiry and collective knowledge advances. For RQ3, we examined differences between the two classes, and the prediction was that students in the principle-based KB class would perform higher than students in the regular KB class on KF participation, metadiscourse processes and conceptual understanding.

3. Methods

3.1. Participants and context

The participants were sixty Year 1 university students, aged 18 to 20, from two classes in a Sino-British program in Shanghai, China. The classes — one knowledge-building principle-based class (KBP) (six males; 24 females), and one knowledge-building regular class (KBR) (five males; 25 females) — were similar in academic levels and gender compositions. The course on Introduction to Business aimed to develop students' business knowledge and academic literacy including conceptual understanding, writing and research skills. The course lasted for 16 weeks; each week, the students spent 1.5 h in in-class discussion, and wrote computer notes on KF after class. Both classes used English as the medium of instruction, and were taught by the same teacher. All participants were informed of the study and signed consent forms before the instruction commenced.

3.2. Pedagogical design

3.2.1. Design of principle-based knowledge building environment

The KBP class was a principle-based environment supported by technology, pedagogy, and principles. The students were encouraged to view KF as a collaborative working space for articulating ideas, expressing confusion, seeking explanation, co-constructing and extending new knowledge (Also see Fig. 1). KF *views* provided the collaborative discussion space and KF *scaffolds* (e.g., my theory; I need to understand; new information; a better theory; putting our knowledge together) helped the students to contribute and improve their ideas; *reference notes*, with hyperlinks to other notes in the KF database, supported students' collective work. Different KF affordances were discussed in relation to principles that helped students improve ideas and embark on collective journeys. Four intertwined principles were included.

- *Epistemic agency*. The environment emphasized a knowledge-building approach to teaching and learning, in which the students took epistemic agency and asked questions they deemed important to the community. In classroom and online discourse, they made ideas public by making cards and posters, asking questions, setting learning goals, posing relevant questions, engaging in research, comparing different models, and searching for explanations, collectively. These designs helped them to take agency, and see ideas as public objects and conceptual artefacts for community advancement.
- *Idea Improvement.* The course curriculum encompassed core ideas (e.g. business model analysis, Human Resource (HR) management, etc.) with which the students worked as objects of inquiry, elaborating, refining, and revising them in class and online, similar to the theory revision process in scientific inquiry. Instead of obtaining answers from the teacher, they engaged in a deepening cyclical process of question, explanation, further question, and further explanation for idea improvement and theory building.
- *Community knowledge.* The students were exposed to group projects and collaborative work, which immersed them in a community ethos and prepared them for democratic, engaging, and challenging inquiry. They developed an awareness of working with classmates to improve their understanding, and extend existing knowledge. They searched for authoritative information to support their arguments, build on others' ideas, synthesize and rise-above using reference notes in pursuit of community knowledge advances. The teacher was a community member, facilitator, and co-inquirer.
- *Reflective and transformative assessment*. Through transformative assessment, the students reflected on and assessed their own and the community's knowledge to improve conceptual understanding and collective knowledge. Specifically, they: (i) composed KF portfolios to track and reflect on their KF inquiries and discourse; (ii) wrote rise-above KF notes using reference notes to emphasize idea monitoring and rise-above for collective understanding; and (iii) conducted reflective presentations in classroom discourse on high-points of KF discourse, using such scaffolds as "*What we have achieved so far*" and "*What can we do next.*" The community used *meta*-socio-cognitive conversations to depict what knowledge advances they had made, connect new and prior knowledge, and set new inquiry goals.

3.2.2. Comparison class

Both classes used the same curriculum materials, wrote KF notes after class, and submitted portfolios. The comparison class was a regular, technology-supported knowledge-building environment (KBR), employing KF for collaborative interaction. The class was neither didactic nor teacher-dominated; the students participated actively in online and offline discussions and focused on creating

good ideas and building onto those of others. However, without principle-based support, they could easily ignore community advancement and the notion that ideas were improvable. While the KBP class had more explicit discussions on KB principles, and emphasized collective progress; the KBR class was more curriculum-oriented, and its students focused more on writing good ideas, learning the curriculum, solving the tasks, and interacting with others.

3.3. Measures

3.3.1. KF participation

The students' KF participation was measured by log files, using a) the Analytical Toolkit (ATK) and b) Applet tools developed with KF. We included ATK indices commonly used in knowledge-building research (Law & Lai, 2006; van Aalst & Truong, 2011), including (i) number of notes created (written); (ii) number of scaffolds (e.g., my theory, I need to understand); (iii) number of revisions; (iv) number of reference notes (notes hyperlinked to other notes); (v) percentage of notes read; (vi) percentage of notes linked; and, (vii) percentage of notes with key words. Scaffolds are thinking prompts (e.g., I need to understand, my theory) that reflect students' metacognitive processes when explaining their work; revision also shows a meta-cognitive and non-linear approach to KB. Applet is an embedded KF tool that generates Read Density and Build-on Density reports, which have been characterized as depicting students' community awareness and community connectedness, respectively (Zhang, Scardamalia, Reeve, & Messina, 2009).

3.3.2. KF e-portfolios: reflective and metadiscourse processes

Students' reflective and metadiscourse processes in their KF e-portfolios were examined to analyze how reflective assessment supported knowledge building. Based on an assessment design adapted from earlier research (Lee et al., 2006; van Aalst & Chan, 2007), students worked in groups and wrote an e-portfolio identifying clusters of notes (i.e., discussion episodes) from their KF discourse that best exemplified community knowledge growth. Each five-student group submitted three e-portfolios (in Weeks 4, 7, and 10). Qualitative analyses were conducted of e-portfolios in both KBP and KBR classes, using interactive top-down and bottom-up approaches to verbal data (Chi, 2011). A coding scheme identified nine strategies characterizing students' reflective understanding and engagement in knowledge building (see Table 1).

Table 1 shows the coding descriptions with examples; the nine strategies can be grouped into three levels. At level 1, students focused on sharing of information that included “Listing and copying” of others' information and “Making simple summary”; at level 2, students' reflection on discussion focused on knowledge construction that included strategies of “Interpretation or elaboration” of KF writing, “Question-based discussion” with questions as the foci, “Constructive use of information and evidence” to support inquiry, and “intertwined question-explanation” process of problem-solving; at level 3, students engaged in metadiscourse processes and community aspects that included strategies of “Meta-cognition” (reflecting on knowledge gaps, highpoints), “Meta-theory” (focusing/reflecting on theories and conjectures while developing discourse and ideas), and “Meta-conversation” (reflecting on the discourse, synthesizing what had been examined, and identifying collective gaps and growth areas). These three levels resembled discourse patterns depicting knowledge sharing, knowledge construction and knowledge building (van Aalst, 2009). Using the coding scheme, the first author did all the rating; a second knowledge-building researcher coded 30% of the portfolios, and the inter-rater reliability was .81.

3.3.3. KF discourse: collective knowledge advances and metadiscourse processes

We also examined how students engaged in metadiscourse processes when writing on KF: the reflective assessment design prompted students to step back and “put their knowledge together” when writing on KF, synthesizing ideas and writing rise-above notes using reference notes that include hyper-links to others' notes/ideas (see Section 3.2.1).

Discourse threads and collective knowledge. Students' collective knowledge growth in KF written discourse was examined. KF Notes were parsed into clusters of notes (thematic inquires) adapted from inquiry threads that addressed a shared key problem (Zhang et al., 2007). Threads were coded as high, medium, or low collective knowledge advances (HKA, MKA and LKA) that reflect domain understanding and conceptual quality of knowledge advances (see Table 2). Two raters coded all clusters including 23 clusters in KBP class and 13 clusters in KBR class, and the inter-rater reliability was .83.

Metadiscourse processes: reference notes and rise-above. We examined metadiscourse in KF discussion focusing on community aspects that included quantitative and qualitative indices. We counted the occurrence of “reference notes”, as a quantitative measure of students' efforts to engage in collective work. KF affordance includes use of reference notes that are links to others' ideas, and the use of reference notes reflect community connectedness as students bring in different classmates' ideas and synthesize them to help them advance their inquiry (i.e., similar to the use of references in scholarly writing).

Students' KF discourse was also coded qualitatively for their engagement in metadiscourse; the students were encouraged to reflect and put knowledge together. Fig. 2 provides an example of students engaging in metadiscourse and rise-above: A group of students were inquiring into a problem, posing explanations and conjectures; Student LW deepened the inquiry by reflecting on the group discourse, summarizing and synthesizing collective ideas, and raising a new question. While the use of reference notes on its own may not be considered as metadiscourse, it provided useful indicators and pointed to important parts of KF discourse for identification of metadiscourse processes. The metadiscourse process in online KF discourse provides additional ways to examine how students' engagement in community work and rise-above influences the conceptual growth of their discourse. Students' discourse threads were coded for the metadiscourse moves and the inter-rater reliability, conducted on 30% of the threads, was .91.

Table 1
The coding scheme of reflective portfolio strategies in knowledge building.

Categories	Description	Exemplar excerpts from e-portfolios
1. Listing and Copying (LC)	Lists notes without explanations; copies information from or repeat other's notes in a very close way	… There is no denying that HRM is important. Let us see what XW's opinion, "*Recently I read a story about Haier … the leader thinks HR is basic …*"* *Content in quotation marks is a copy of Student XW's note information
2. Brief Summary (BS)	Summarizes a few notes shortly and often incompletely	I have read our classmates' ideas … So, a good manger must have these principles. *First, …Second,. Third, …*
3. Interpretation or Elaboration (IE)	Interprets others' notes information with different wording or extend information by examples or evidence	Concerning how to select employees, LW got some information indicating that more than half people believe … *That is to say,* it is ….
4. Question-Based Discussion (QBD)	Sees the discussion as question-based and a deepening process of seeking answers to questions	FXX *brings forward her question,* how to establish a system to assess performance …. LCH *gave her answer* … then WY *gave an answer in another situation* … YIM *brings an idea* which is *totally different from others … she thinks* ….
5. Constructive Use of Information (CUI)	Uses information, either from experts, books, internet, or other related courses, life experience, etc. to justify or deepen the ideas	From the note theories from experts about analyzing people contributed by FTY, I learnt some psychological theories such as *Maslow's hierarchy of needs*, which divided human needs into five layers and …
6.Intertwined Question-Explanation (IQE)	Keeps asking related questions, showing doubts or seeking clarification; responses and explanations are intertwined progressively in the discussion	The *main question* was raised by JHL … many students *took part in the discussion actively*. ZLY said … and *summarized* her idea … However; CXB seemed to [*differ*] *with* her. She thought … and put *a further question* … This *problem* was tough. CJR gave *a general answer* … this answer *didn't respond to the question directly,* we can work on this later … While WY was *confused about* … CXB offered *another aspect* of the problem …
7. Meta-Cognition (MC)	Reflects on what the class does not know; realizes high points in the discussion; self-defines goals and tasks for exploration	At the beginning of this semester, *we knew little about* HRM, we tried to imagine … We now showed a *great understanding of* it. … The third topic came up with XB, it's interesting when she wrote a note Let's start a new topic! *This is like a class without a teacher* …
8.Meta-Theory (MT)	Focuses on theories while developing the discourse; uses theories/conjectures to explain business phenomena, even with attempts to create new theories	I feel amazed at her note … She studies *some HR theories* and tries to justify her ideas *by these theories* … HR *Theory Y* is the most appropriate one that can be used … Based on these expanded ideas, we actually have *created a theory on* what makes an excellent HR manager …
9. Meta-Conversation (MCV)	Focuses on examining what the discourse is about, especially reflecting on discourse goals; adopts a "*we*" perspective to assume collective responsibility for advancing knowledge; tackles difficult/important issues which may be neglected by the community	The discussion is quite complicated … LC raised *new questions* … WY didn't answer them immediately; *Instead, five other students gave their explanations to the questions* … Among all these notes … Two of the five notes are *even further discussed*. … LCH thought WQ's theory can't explain the questions I hope *we classmates can solve the problem* … This topic has *not been widely discussed yet* … it is quite *new and interesting* … Ultimately, *we* arrived *at a new conclusion* …

Table 2
Classification of discourse threads by conceptual quality and knowledge advances.

Level	Description
Low	This thread included responses and interactions that primarily consisted of sharing of information focusing on overly general understanding and/or naïve ideas; lacked a well-developed treatment of business concepts.
Medium	This thread included explanations and arguments that addressed questions from diverse perspectives; a range of business ideas were discussed; indication of constructive understanding but lacked deep insights or sustained inquiry.
High	This thread included core ideas and progressive improvement identifying and addressing gaps in collective knowledge; sustained idea improvement with conceptual depth; deepened and formulated sophisticated views about business theories or concepts.

3.3.4. Conceptual understanding

The students' conceptual understanding, including their conceptual inquiry and academic literacy, was examined using three measures based on the assessment of the Program.

Group Inquiry. Each five-student group designed a Human Resource (HR) research project, conducted inquiries in authentic sites for collaborative problem-solving, and collectively wrote a report. The purpose of this activity was to assess students' conceptual inquiry, domain understanding and competence in addressing research problems including research design, data analysis and writing. The scoring of the research reports followed the rubrics set by the Program. All reports were first blind-rated by the first author; 50% of the reports were scored by another course teacher of the Program, and the inter-rater reliability was .90.

Individual inquiry. The individual report examined students' conceptual understanding and application of the PEST (political,

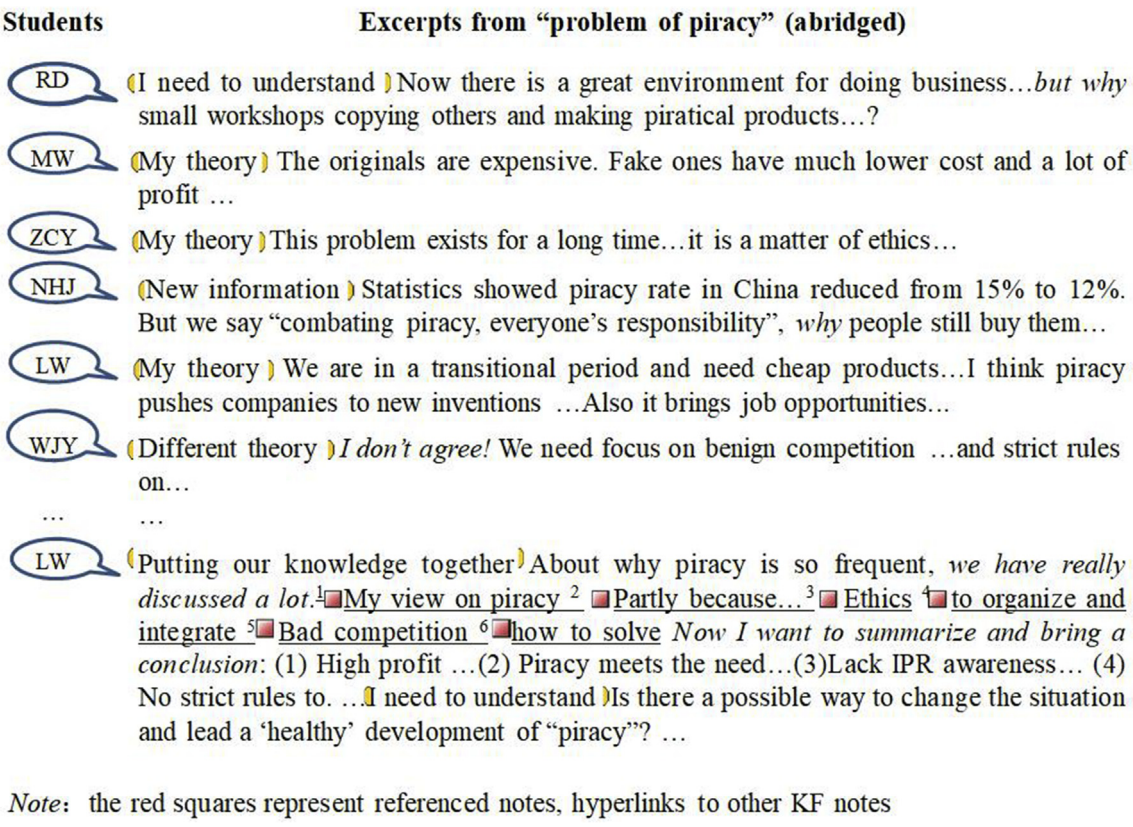

Fig. 2. An example of a metadiscourse move in an inquiry thread.

economic, social, and technological) model for real-life problems in business. All reports were blind-rated by the first author; 50% of the reports were scored by another course teacher, and the inter-rater reliability was .92.

Essay and case study. The students' essay writing and case analysis were assessed in their end-of-the-year examination, which tested their attainment of business knowledge, analytical thinking, and language proficiency. All test papers were blind rated by a three-teacher team; discrepancies were discussed and differences were resolved and the marks agreed upon were used for scoring.

4. Results

4.1. KF participation and conceptual understanding

4.1.1. Database usage and changes of KF participation

We first reported on the general database usage and patterns of KF participation for both classes and examined the prediction of KF participation on conceptual understanding. Table 3 shows ATK indices for both classes over the instructional period, illustrating the students' active engagement. Specifically, for KBP class, the students on average created (wrote) 57.8 notes and read 47.2% of notes, suggesting a high level of contribution and connectedness. Fig. 3 shows collective KBP student participation based on KF Applet-based indices, by tracking changes in *Read* and *Build-on* densities at three times. *Read* densities were 65.4% (Month 1), 86.5% (Month 3), and 91.4% (Month 8), while *Build-on* rates were 19.5%, 47.1% and 63.4%, respectively. This suggests that the students were engaged actively with increasing community awareness and community connectedness in their KF online collective inquiry (Zhang et al., 2009).

For the KBR class, the ATK indices showed a mean of 24.4 notes-created (SD = 9.6) and 23.9% notes-read. KF Applets generated

Table 3
Means and standard deviations (in parentheses) of AKT indices in KBP and KBR classes.

	# of notes created	# of scaffolds used	# of revisions	# of reference notes	% of notes read	% of notes linked	% of notes with key words
KBP	57.8 (18.9)	42.5 (26.5)	16.8 (12.8)	63.4 (17.9)	47.2 (15.3)	78.2 (10.7)	55.8 (22.6)
KBR	24.4 (9.6)	6.1 (8.4)	7.6 (9.1)	25.3 (9.7)	23.9 (12.4)	51.7 (16.2)	36.1 (19.5)

KBP: KB principle-based environment; KBR: KB regular environment.

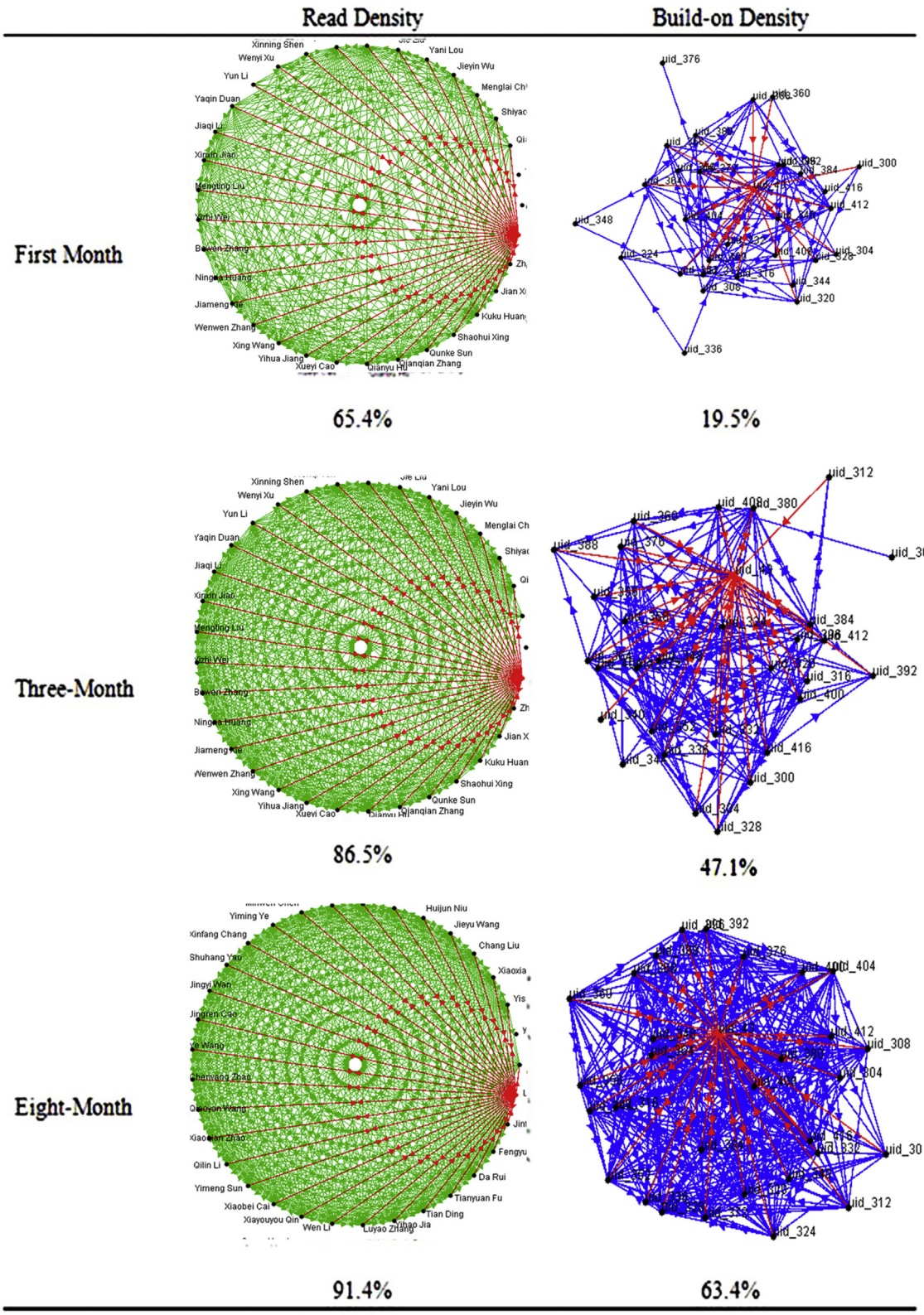

Fig. 3. Read and Build-on densities in the principle-based KB class over time.

Table 4
Zero-order correlations between ATK indices, individual inquiry, group inquiry, and essay & case in KBP class (N = 30).

	1	2	3	4	5	6	7	8	9	10
1. Notes created	_									
2. Scaffolds used	.50**	_								
3. Notes revision	.45*	.47**	_							
4. Notes read	.41*	.39*	.17	_						
5. Reference notes	.09	.17	.14	-.18	_					
6. Notes linked	-.12	.05	-.39*	-.04	.21	_				
7. Notes with key words	-.14	.10	-.08	-.25	.35	.59**	–			
8. Individual inquiry	.41*	.50**	.39*	.29	-.01	-.03	.06	–		
9. Group inquiry	.69**	.49**	.47**	.32	.21	.03	.01	.49**	–	
10. Essay & cases	.45*	.54**	.48**	.23	.30	-.11	.06	.28	.55**	–

*$p < .05$, **$p < .01$.

increasing *Read* densities through Month 1 (58.1%), Month 3 (64.4%), and Month 8 (86.7%); *Build-on* densities also increased (8.3%, 16.8%, and 32.2%, respectively). These results suggest that the students in both classes had high levels of KF participation with increasing contribution and connectedness over time.

4.1.2. Prediction of KF participation on conceptual understanding

Tables 4 and 5 show the correlations between ATK indices and conceptual understanding in the KBP and KBR classes, respectively.

The analysis showed that the KF note-creation reflecting KF contribution was significantly correlated with different measures of conceptual understanding in the KBP (ranging from $r = .41$ to .69) and KBR (from $r = .47$ to .65) classes. The scaffolds and revisions, reflecting meta-cognitive processes, were shown to be correlated with all academic measures (ranging from $r = .39$ to .54) only in the KBP class (Tables 4 and 5). The predictive effect of KF participation for conceptual understanding was examined. A KF "Participation" score, for the combined classes, was created via factor analysis of the seven ATK indices; the factor score explained 53.6% of the variance. The three learning outcomes were also combined into one variable, Conceptual Understanding. Hierarchical regression showed that the students' prior achievement (matriculation score) contributed significantly to conceptual understanding ($R^2 = .08$, $F(1, 58) = 5.47$, $p < .05$); when KF "Participation" was entered, an additional 27% of the total variance was explained ($R^2 = .35$, $F(2, 57) = 15.17$, $p < .001$). The students' KF participation predicted their conceptual understanding over and above their prior academic achievement.

4.2. Reflective processes, metadiscourse and knowledge advances

The second question examined the nature of reflective processes and metadiscourse, and investigated how the identified strategies were associated with students' conceptual understanding and knowledge advances.

4.2.1. Reflective processes and metadiscourse in KF e-portfolios

Reflective processes for high-low groups. Based on the qualitative analyses of the e-portfolios (see Methods), nine different strategies were identified in group e-portfolios. The students' use of reflective strategies was developed collectively and situated within the group, and conceptual understanding was measured on a group basis (group report and inquiry). Contrasting group analysis (common in Learning Sciences research, Hmelo-Silver, 2003) was employed and separate analyses for KBP and KBR classes were reported: for the KBP class, the student groups were classified into high (Groups 3, 4, & 5) and low-performance groups (Groups 1, 2, & 6), based on group research/inquiry. Table 6 shows the mean frequencies and SDs of different reflective strategies in the groups.

LPGs: low-performance groups; HPGs: high-performance groups; LC: listing & copying; BS: brief summary; IE: interpretation or elaboration; QBD: question-based discussion; CUI: constructive use of information; IQE: intertwined question-explanation; MC: meta-

Table 5
Zero-order correlations between ATK indices, individual inquiry, group inquiry and essay & case in KBR Class (N = 30).

	1	2	3	4	5	6	7	8	9	10
1. Notes created	_									
2. Scaffolds used	.30	_								
3. Notes revision	.64**	.03	_							
4. Notes read	.17	.01	.10	_						
5. Reference notes	.31	-.16	.41*	-.11	_					
6. Notes linked	-.23	.10	-.38*	-.25	-.37*	_				
7. Notes with key words	-.02	.31	-.04	-.15	-.43*	.03	_			
8. Individual inquiry	-.07	-.28	-.19	.28	.05	-.09	.04	_		
9. Group inquiry	.65**	.10	.43*	.30	.41*	-.18	-.15	.40*	_	
10. Essay & cases	.47**	.03	.16	.02	.29	-.14	.16	.27	.38*	_

*$p < .05$; **$p < .01$.

Table 6
Mean frequencies and standard deviations (in parentheses) of reflective portfolio strategies in low-high performance groups in KBP class.

	LC	BS	IE	QBD	CUI	IQE	MC	MT	MCV
LPGs	.67 (.49)	1.67 (1.29)	3.00 (.85)	7.33 (2.13)	2.67 (1.29)	4.33 (1.76)	5.00 (.85)	1.67 (.98)	2.33 (1.76)
HPGs	.00 (.00)	1.33 (.49)	3.67 (.98)	4.00 (.85)	2.67 (.98)	5.67 (.98)	6.33 (1.76)	3.33 (1.76)	4.33 (1.29)

cognition; MT: meta-theory; MCV: meta-conversation.

Multivariate analyses of the reflective strategies were conducted; and follow-up univariate analyses showed that the high-low performance groups differed significantly on six strategies. The low-performance groups obtained higher scores on Listing and Copying (F (1, 28) = 28.0, $p < .001$, $\eta^2 = .50$) and Question-based Discussion (F (1, 28) = 31.8, $p < .001$, $\eta^2 = .53$), while the high-performance groups scored significantly higher on Intertwined Question-Explanation (F (1,28) = 6.6, $p < .05$, $\eta^2 = .19$), Meta-cognition (F (1, 28) = 7.0, $p < .05$, $\eta^2 = .20$), Meta-theory (F (1,28) = 10.3, $p < .005$, $\eta^2 = .27$), and Meta-conversation (F = (1, 28) = 12.6, $p < .005$, $\eta^2 = .31$). There were no significant differences for Brief Summary (F (1, 28) = .86, $p = .36$, $\eta^2 = .03$), Interpretation/Elaboration (F (1, 28) = 4.0, $p = .06$, $\eta^2 = .13$), or Constructive Use of Information (F (1, 28) = .00, $p = 1.0$, $\eta^2 = .00$).

Metadiscourse processes for high-low groups. Further analyses were conducted to examine the role of high-level metadiscourse processes in conceptual understanding. The three high-level strategies (MC, MT, and MCV) were combined into a Metadiscourse Strategy, which was examined for change and over time (Portfolios 1, 2, and 3). A 2 × 3 (High/Low Group X Portfolio Phase) repeated measures on metadiscourse strategy analysis showed a significant time effect, (F (2, 27) = 4.20, $p = .05$, $\eta^2 = .13$) and a group effect, (F (1, 28) = 13.82, $p < .005$, $\eta^2 = .33$). A significant main interaction effect between time and group was obtained (Wilks' Lambda = .66, F (2, 27) = 8.40, $p < .005$, $\eta^2 = .23$), indicating that the high-low groups differed in changes in meta-discourse strategy. Fig. 4 depicts the metadiscourse moves across the three phases in both groups, showing a generally positive upward trajectory of metadiscourse processes over time.

For the KBR class, similar patterns were obtained (Table 7). The high-low groups differed on Question-based Discussion (F (1, 28) = 16.8, $p < .001$, $\eta^2 = .39$), with higher scores for the low-performance groups. There were also differences for Intertwined Question-Explanation (F (1, 28) = 21.44, $p < .001$, $\eta^2 = .44$), Meta-cognition (F (1,28) = 6.25, $p < .05$, $\eta^2 = .18$), Meta-theory (F (1, 28) = 7.0, $p < .05$, $\eta^2 = .20$), and Meta-conversation (F= (1, 28) = 42.86, $p < .001$, $\eta^2 = .61$), with higher scores in high-performance groups. There were no significant differences for the other four measures. As well, Metadiscourse Strategy was examined using repeated measures over time (Group x portfolio phase); significant time (F (2, 27) = 23.41, $p < .01$, $\eta^2 = .46$) and group (F (1, 28) = 12.92, $p < .01$, $\eta^2 = .32$) effects were obtained favoring the high-performing groups and there were no interaction effects. These results suggest that the students using higher-level reflective and metadiscourse strategies performed better on conceptual understanding in group inquiry.

4.2.2. Metadiscourse processes and collective advances in online discourse

Analyses were conducted to investigate the relationships between metadiscourse processes and collective knowledge advances in online KF discourse. As reported in the Methods section, the students' KF discourses were coded into low, medium and high knowledge advances reflecting the extent of knowledge building. The students' use of reference notes was counted as a quantitative index of their engagement in collective work, and the occurrences of metadiscourse moves were coded (see Fig. 2).

Table 8 shows the frequencies of reference notes and metadiscourse moves among discourse threads of different conceptual qualities. For the KBP class, a significant difference was obtained for the frequency of reference notes for quality of discourse threads (F (2, 20) = 4.63, $p < .05$, $\eta^2 = .32$), and post-hoc analyses indicated differences between LKA and HKA, F (1, 12) = 8.87, $p < .05$. Similarly, a significant difference for rise-above metadiscourse moves was obtained for quality of threads, F (2, 20) = 7.00, $p < .01$, $\eta^2 = .41$; and the post-hoc analyses indicated differences between LKA and HKA, F (1, 12) = 15.68, $p < .01$; as well as MKA and HKA, F (1, 14) = 5.29, $p < .05$. These findings indicate that discourse threads showing higher conceptual quality also included higher frequencies of reference notes and metadiscourse moves.

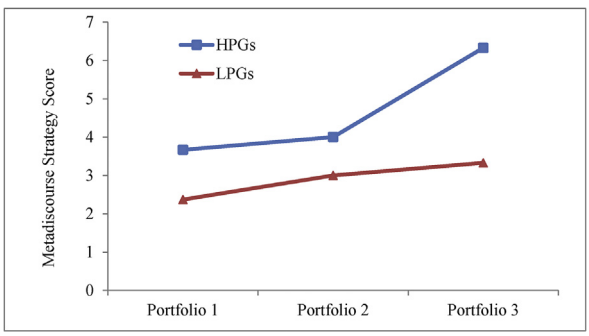

Fig. 4. Metadiscourse strategy in three portfolios for high-low performance groups.

Table 7
Mean frequencies and standard deviations (in parentheses) of reflective portfolio strategies in low-high performance groups in KBR class.

	LC	BS	IE	QBD	CUI	IQE	MC	MT	MCV
LPGs	2.67 (2.44)	2.33 (.98)	2.33 (1.29)	6.00 (1.69)	5.33 (.98)	.67 (.98)	1.33 (1.29)	.00 (.00)	.33 (.49)
HPGs	1.33 (.98)	2.00 (2.24)	3.00 (2.24)	4.00 (.85)	5.33 (2.13)	3.00 (1.69)	3.00 (2.24)	1.00 (1.46)	2.67 (1.29)

Table 8
Mean frequencies and standard deviations (in parentheses) of reference notes and metadiscourse moves in LKA, MKA, and HKA threads in KBP and KBR classes.

KBP class (N = 23)			KBR class (N = 13)		
Threads (No.)	Reference Notes	Metadiscourse	Threads (No.)	Reference Notes	Metadiscourse
LKA (7)	1.43 (3.78)	1.00 (1.15)	LKA (7)	0.29 (0.76)	0.57 (0.53)
MKA (9)	6.33 (6.76)	2.00 (1.41)	MKA (5)	1.00 (1.00)	1.40 (1.14)
HKA (7)	12.71 (9.29)	3.57 (1.27)	HKA (1)	3.00 (0.00)	3.00 (0.00)

LKA: low-level knowledge advances; MKA: medium-level knowledge advances; HKA: high-level knowledge advances.

For the KBR class, similar results were obtained with low-, medium-, and high-level threads differing significantly on Reference Notes (F (2, 10) = 4.63, $p < .05$, $\eta^2 = .48$) and Metadiscourse Moves (F (2, 10) = 4.35, $p < .05$, $\eta^2 = .46$). Post-hoc analyses indicated differences between LKA and HKA on Reference Notes (F (1, 6) = 11.28, $p < .05$, $\eta^2 = .65$) and Metadiscourse Moves (F (1, 6) = 18.06, $p < .01$, $\eta^2 = .65$), respectively.

4.3. Role of principles on knowledge-building processes and knowledge advances

The third research question examined whether there were differences between the principle and non-principle based classes in KF participation, metadiscourse processes and conceptual understanding.

4.3.1. Differences in KF participation

As reported in Section 4.1, both classes were involved actively, and increased their read and build-on densities over time. MANOVA comparison analyses of KF indices showed that the KBP and KBR students differed in number of *Notes Created* (F (1, 58) = 74.1, $p < .001$, $\eta^2 = .56$), *Notes Read* (F (1, 58) = 42.0, $p < .001$, $\eta^2 = .42$), and *Notes Linked* (F (1, 58) = 56.2, $p < .001$, $\eta^2 = .49$). These results suggest that the students in the principle-based class were involved in more KF contributions and connectedness in database usage.

4.3.2. Differences in metadiscourse in portfolios and online discourse

Differences in reflective and metadiscourse processes in portfolios. MANOVA indicated that the KBP class scored higher on four reflective strategies in the portfolio: Intertwined Question-Explanation (F (1, 58) = 53.14, $p < .001$, $\eta^2 = .48$), Meta-cognition (F (1, 58) = 59.94, $p < .001$, $\eta^2 = .50$), Meta-theory (F (1, 58) = 30.26, $p < .001$, $\eta^2 = .34$), and Meta-conversation (F (1, 58) = 17.81, $p < .001$, $\eta^2 = .24$). The KBR class scored higher on Listing and Copying (F (1, 58) = 20.71, $p < .001$, $\eta^2 = .26$) and Constructive Use of Information (F (1, 58) = 54.59, $p < .001$, $\eta^2 = .49$). There were no statistically significant differences in the other strategies.

As reported before, the three high-level community-based reflective strategies were combined to form a Metadiscourse strategy. A 2 × 3 (Environment x Portfolio Phase) repeated measures ANOVA showed a significant main effect for environment (F (1, 58) = 52.05, $p < .001$, $\eta^2 = .47$), indicating the KBP students used more high-level metadiscourse strategies. No significant main effect was obtained for portfolio phases, nor for interaction effects between environment and time.

Differences in reflective-metadiscourse processes in online discourse threads. A 2 × 3 (Environment X Quality of threads) ANOVA showed discourse threads in KBP and KBR classes differed significantly on Reference Notes (F (1, 34) = 7.13, $p < .05$, $\eta^2 = .17$) and Metadiscourse (F (1, 34) = 4.84, $p < .05$, $\eta^2 = .13$), indicating that the KBP students used more reference notes in the online discourse, and they were more engaged in rise-above metadiscourse moves (Table 8).

4.3.3. Differences in conceptual understanding and knowledge advances

Table 9 shows the means and SDs for different measures of conceptual understanding for both the KBP and the KBR classes.

Table 9
Means and standard deviations (in parentheses) for group inquiry, individual inquiry, and essay & case in KBP and KBR classes.

	Group inquiry	Individual inquiry	Essay & case
KBR (N = 30)	80.33 (4.97)	77.87 (7.16)	76.50 (8.47)
KBP (N = 30)	83.67 (4.61)	82.13 (5.79)	78.00 (7.07)

Multivariate analyses on these measures indicated significant environment effects for group inquiry (F (1, 58) = 7.25, $p < .01$, $\eta^2 = .11$) and individual inquiry (F (1, 58) = 6.44, $p < .05$, $\eta^2 = .10$), both favoring the KBP class; there were no statistically significant differences for essays & case (examination score). For collective knowledge growth (Table 8), the numbers of low-, medium-, and high-knowledge advances threads were seven, nine, and seven, respectively, in the KBP class, versus seven, five, and one, respectively, in the KBR class. These results suggest that the KBP students showed higher-level conceptual quality and richer collective knowledge in the discourse threads.

5. Discussion

This study examined the design of reflective assessment and the processes of metadiscourse that promoted productive discourse supported by principles in a knowledge building environment. The findings indicate that the designed environment had an effect on the students' active contributions and connectedness and growth over time, and that the students' KF participation predicted their conceptual understanding. Analyses of the students' e-portfolios indicated a range of reflective strategies, and metadiscourse processes were associated with higher levels of conceptual inquiry and knowledge advances in online writing. While similar patterns and growth were shown in both classes, the students in the principle-based class showed higher levels of KF participation, metadiscourse, and conceptual understanding. The role of metadiscourses and reflective assessment supported by principles in promoting productive discourse, and the implications for asynchronous online discussion, CSCL and knowledge building are discussed.

5.1. Knowledge building with reflective assessment design for online participation and conceptual advances

This study has shown the positive effects of the designed knowledge-building environment on students' online participation. Although online forums are popular, discussion threads are often dispersed and shallow (Calvani et al., 2010; Hewitt, 2005), with limited student contributions (Hew & Cheung, 2012b, pp. 31–48). Our findings using the KF environment enriched with reflective assessment show that the students were engaged actively in KF inquiry, with high contributions and connectedness in comparison with other online forums and knowledge-building studies including those undertaken by tertiary students (e.g., Zhao & Chan, 2014; Siqin et al., 2015). There is also evidence of collective work with increasing KF “read” and “build-on” densities reflecting students' developing community awareness and community connectedness over time (Zhang et al., 2009). The quantitative findings are corroborated by the qualitative analysis, illustrating students' metadiscourse processes, rise-above notes and collective knowledge advances. As the students were involved in reflecting and reviewing what the groups and community had achieved, they would have to read and process different notes (questions and ideas), consider alternative models, and synthesize fragmented understanding for further inquiry; and that would have helped with their contributions and sustained the inquiry.

This study has also demonstrated how the designed environment fostered students' conceptual understanding. Regression analyses showed that the KF participation predicted overall conceptual understanding that included research inquiry, domain knowledge and academic literacy over and above the students' prior achievement. These findings suggest that the students' contribution in KF was beneficial to their conceptual inquiry, which is similar to our earlier research with tertiary students (Zhao & Chan, 2014). The study's findings further suggest that reflective assessment enriched with principles may prompt meta-cognitive processes: we identified correlations between scaffold use and note revision, both reflecting metacognition, with conceptual understanding in the principle-based KB class. Using scaffolds when writing and revisiting notes from time to time may help students refine their ideas, thus bringing about deeper conceptual understanding; in this study, this relationship was only present in the principle-based class, where epistemic goals were clearer. Knowledge-building approaches in tertiary education, particularly in Asian contexts, draw questions about learning outcomes and understanding. This study contributed to CSCL research and tertiary education context in Mainland China, where collaboration has been shown to be difficult (Ge, 2011) and CSCL research is now just emerging.

5.2. Metadiscourse and reflective assessment in fostering collaborative knowledge building

This study examined the processes and strategies students used in reflective assessment that support sustained inquiry and knowledge advances. Research on forum discussions has shown how tools, models and pedagogy facilitate asynchronous online discussion (Loncar et al., 2014). In the same vein, we analyzed the portfolio and identified a range of reflective strategies. The findings indicated writing portfolios was helpful but not adequate – some focused on good discussion as sharing and paraphrasing of information; others emphasized good discussion focusing on questions, explanation and sources of information; and, at a high level, the students shifted from individual to collective and focused on community knowledge and discourse development as an object for reflection and inquiry. The range of reflective strategies seemed consistent with discourse patterns of knowledge sharing, knowledge construction and knowledge building (van Aalst, 2009) in online writing and we identified the different manifestations of these reflective processes in knowledge-building portfolio writing.

This study has enriched the nature and dynamics characterizing metadiscourse. Typically, metadiscourse in studies of linguistics generally focuses on social practice and turns taking (Resendes et al., 2015). In knowledge building, metadiscourse as ‘discourse about the discourse”, has epistemic meanings – it is concerned with how students develop a higher-level process of discourse as they progress towards collective knowledge (Bereiter & Scardamalia, 2016). This study suggests three inter-related dimensions: (1) meta-cognition – students have an ‘aha’ experience of what they did not know and how they now understand more based on community processes; (2) meta-theory – students are aware of concepts of community interest; explicitly noting theorizing efforts to construct new conjectures and theories; and (3) meta-conversation – students track the development of the group/community discourse,

discuss collective advances they have made and formulate further inquiry. Primarily, metadiscourse in knowledge building can be multi-faceted, including collective reflection on cognition, concepts and conversation. Metadiscourse is concerned with collective work, and online forum findings corroborate portfolio findings, showing that the students used more reference notes (hyper-links to other notes). They also engaged in meta-conversation and rise-above, "putting their knowledge together" for advancement. These different aspects of metadiscourse reflect the students' high-level shared epistemic agency that contributed to collective advances. The analysis of metadiscourse has provided pointers to characterize and scaffold knowledge-building processes for collective and sustained inquiry that needs further investigation.

This study has developed a new design that enriches online discussion and metadiscourse. Although knowledge-building approaches have been implemented and researched widely (see review, Chan, 2013; Chen & Hong, 2016), metadiscourse does not emerge easily (van Aalst, 2009). Siqin et al. (2015) found that opportunistic collaboration generated higher-level questions and ideas, but that students made little use of metadiscourse. Knowledge-building talk only brings about metadiscourse if there is collective reflection on the knowledge-building discourse (Resendes et al., 2015). This study employed multiple innovative strategies to promote metadiscourse: (1) the students collectively reflected on their discourse writing group portfolios; (2) they reflected on idea development putting knowledge together in online discourses; and (3) their KF writing was supported by student-led classroom sharing, reviewing what knowledge progress the class community had made and what new questions emerged. We extended earlier research on e-portfolio assessment by designing continual assessment, involving three portfolios to make assessment more transformative – the students build on their Portfolio 1 enquiries through Portfolios 2 and 3, and concurrent feedback helped to transform their knowledge. Reflective assessment design involved both online and offline discourse – the students wrote online rise-above notes and synthesized key knowledge advances in classroom discourse, and metadiscourse helped to prompt their collective inquiry further.

The reflective assessment design in this study has helped to foster both collective and individual knowledge advances. According to Scardamalia (2002), reflective assessment can be *embedded* in curricula and inquiry, *concurrent* with continual feedback and *transformative* with deepening inquiry. It is known that reflection is key to learning, and inquiry without reflection is limited (Sandoval, 2005). Similarly, just writing on online forums is not adequate; students need to reflect on their writing and inquiry since online discussion without reflection might result in shallow talks. It is important to design strategies to improve student groups' metacognitive, monitoring, and reflection capabilities (Calvani et al., 2010). The reflection in this study, prompted by such scaffolds as "what we have achieved so far" and "what other questions we have", reinforced metadiscourse and a collective awareness of the community's concerted efforts. Students work on the current state of knowledge and goals for next-step inquiry, which shall enhance their own and groups' knowledge growth.

5.3. The intertwined effects of knowledge-building principles and reflective assessment

This study is one of the few studies comparing principle-based (KBP) and non-principle-based (KBR) knowledge-building classrooms. Principle-based innovation is key to knowledge building (Hong & Sullivan, 2009); however, there is a lack of empirical evidence on effects of principles. This study showed both classes improved on various measures of participation, process and outcomes, and the effects were stronger in the KBP class. KB principles provide goals for students to strive for, and objects for inquiry and improvement (Zhang et al., 2011). Reflective assessment enhanced with principles helps to bring about metadiscourse that in turn supports collective knowledge growth.

Several key KB principles were interwoven with reflective assessments: the students focused on knowledge-building principles and reflected on their individual/group understanding. For example, when *community knowledge* was an epistemic prompt, it helped the students to engage in metadiscourse to examine and trace their community's learning/knowledge progress, learning achievements, and learning gaps through connecting with others and reflecting on growth. They used scaffolds such as "I have something new to offer …", "what we have achieved so far" or "putting our knowledge together", focusing on collective growth. When metadiscourse was developed (e.g., rise-above notes), it helped to objectify the students' knowledge artefacts, and helped them to understand the principle of *community knowledge* better. Through the cyclical and interactional process, the students gradually realized they were not just focusing on individual outcomes but embarking on a journey towards a collective endeavor.

Our comparative intervention design helped to illuminate underlying/deeper knowledge-building processes. In the principle-based environment, the students took agency connecting different ideas such as writing "another point to add", "in addition to what we have discussed", or "what we still need to understand", to indicate the community awareness of building knowledge together as an ethos of the community. Without a deliberate effort using principles to advance community knowledge, students in the non-principle-based environment might feel content with personal learning. In terms of design, we suggest a *dual* approach of reflective assessment and principles to enhance collective knowledge advances. Knowledge building principles provide criteria for students to engage in collective inquiry (Scardamalia & Bereiter, 2014; Scardamalia, Bransford, Kozma, & Quellmalz, 2012); and reflective assessment helps them reflect upon and consolidate their understanding of these principles; these interactive dynamics reciprocally prompt them to use metadiscourse processes to improve the quality of KF discourse.

5.4. Limitations and contribution of the study

5.4.1. Limitations and further research

This study had a comparison design, but in complex classroom settings it is difficult to control all variables (Salomon, 1996) and we may not have identified other relevant factors affecting our results. The focus of this paper was to examine metadiscourse in reflective assessment, and future study would include different factors impacting upon students' knowledge building inquiry. A

second limitation is that the researcher was the teacher, possibly creating a halo effect for the KBP class; however, the study was conducted within an established international joint program and the institutional regulation makes it important that good practice is followed. While this study has yielded positive results, future research involving less and more experienced teachers working on knowledge building in different classrooms would help to test and illuminate how reflective assessment designs and metadiscourse work in different contexts. A third limitation was the sample size, being too small to permit multi-level analyses; future studies could address this. Due to space limitation, data from the classroom reflective presentations were not discussed; and further work could examine how these classroom presentation/discussion data supplement online discourse.

5.4.2. Theoretical and pedagogical significance

This study contributes to the literature on developing new approaches to conceptualizing and designing online discussion in CSCL. Theoretically, it has advanced the idea of using metadiscourse as a second order layer for analyzing and scaffolding online discourse and CSCL premised on collective knowledge building. As discussed in Introduction, merely placing students together mediated by computers does not bring about effective collaborative interactions (Calvani et al., 2010; Damşa, 2014; Kreijns et al., 2003). Students' contributions to asynchronous online discussions are often characterized by surface-level thinking and low-level knowledge construction (Hew & Cheung, 2012a; Hewitt, 2005); rise-above/synthesis is generally non-existent (Scardamalia & Bereiter, 2014). Current online discussion research has primarily focused on analyzing task collaboration and interaction, and different strategies have been proposed to promote quality online discussion and discourse (Cesareni et al., 2016; Hew & Cheung, 2012b, pp. 31–48). This study demonstrated a new way of addressing the problem through re-conceptualizing online discussion that goes beyond examining task content, problem solving and social interactions. Metadiscourse, i.e. students' discourse about their discourse, is analogous to cognition and meta-cognition, illustrating another layer of higher-level collective processes for connecting, synthesizing and creating coherent knowledge, and for charting further growth.

While metadiscourse has been recognized as important in knowledge building research, few systematic studies have been conducted. The study has advanced the idea of metadiscourse through illuminating its nature that encompasses different facets relating to *cognition, concept and conversation*. Metadiscourse processes include: (1) reflecting meta-cognitively on community knowledge growth and gaps; (2) theorizing concepts of community interest at a meta-level; and (3) tracking community conversation for knowledge advances. These related processes may provide a framework for further analyses of meta-level and collaborative processes in CSCL and knowledge building. Although this study was conducted in the knowledge-building context using Knowledge Forum platform, the ideas of metadiscourse — with students reflecting on, inquiring into, and talking about their discourse — can be applicable to different discussion forums and CSCL platforms involving collaborative discussions. Designing reflective assessment for metadiscourse processes is important in addressing problems of fragmented talk and enriching productive discourse in online discussion. Knowledge building and CSCL are concerned with collective dynamics, group cognition and productive discourse (Scardamalia & Bereiter, 2014; Stahl, 2006); our inquiry into metadiscourse processes would be pivotal for advancing theories and design of knowledge building and CSCL.

This study also contributes to new ways of designing for online discussion and CSCL. The common approach of online discussion focuses on improving the quality of content and social interaction; it does not clearly include elements of reflection for rise-above and synthesis. Using e-portfolio assessment with principle-enriched design, we have demonstrated how productive online discourse can be developed through the intertwined effects of principles and reflective assessment. The study has shown how to design reflective assessment to promote metadiscourse and knowledge advances through developing continual portfolio assessment (several rounds and questions developed are followed in next round) and rise-above writing in online discourse (i.e., putting our knowledge together).

The design of reflective assessment has been studied in knowledge building environments, but can be transferred to other CSCL designs; after students inquire into certain phenomena collaboratively, they can be encouraged to reflect on their collaborative inquiry processes. While web-based portfolio assessment has been used to help students' reflective behaviors (Chang, Chen, & Chen, 2012), our design goes further, helping students reflect on what they have achieved collectively and set new goals for the next inquiry. Reflection is now commonplace; there can be more or less productive ways of reflection on experience. The range of strategies and metadiscourse strategies in this study can provide prompts and pointers to help students engage in high-level reflective processes. We also need to equip them with both principles as epistemic standards and reflective strategies so they can move from shallow discourse to charting their knowledge building advances.

6. Conclusion

This study has addressed the problems of developing productive discourse and contributed to the literature on online discussion, CSCL and knowledge building through designing and examining metadiscourse in reflective assessment. Specifically, the study has investigated how students reflected on their discourse to chart knowledge advances and elucidated how reflection works through identifying a range of low-, medium- and high-level reflective strategies. The study contributes to the literature on theory and design of CSCL. Going beyond task interaction in collaborative discourse, we advance a different approach conceptualizing the notion of metadiscourse, which is “discourse about discourse”, that encompasses meta-cognition, meta-theory and meta-conversation as key to advancing productive discourse and collective inquiry. The study has demonstrated, conceptually and empirically, how reflective assessment supports metadiscourse processes and knowledge advances, and how these processes and effects can be enhanced in a principle-based environment. This study has provided a holistic perspective on designing and examining processes for knowledge advances in a tertiary education context, which may shed light on the design of CSCL environments using assessment to foster online

learning, discussion and knowledge building. Further research is needed to investigate the nature of online and offline metadiscourse processes in CSCL classrooms, and how they can be developed through reflective assessment.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.compedu.2018.07.006.

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