

Infrastructuring for Collective Cognitive Responsibility: A Case Study of Student Knowledge Building Design Studio

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Abstract: In this paper, we present the design of a two-day student programme called the student Knowledge Building Design Studio (sKBDS), intended to promote collective cognitive responsibility (CCR) by focusing on student interests in real sustainability-related problems and giving them opportunities to drive the collective inquiry. Participants included 36 primary students from three different schools (six interest groups). The design of sKBDS shows how CCR developed over time across interest groups. Our analytical approach included the use of theory building moves to code students' ideas and the use of an analytics tool called "Ideas-Building" to examine collaborative patterns from their online discussions. Our findings suggest a positive impact of the sKBDS design in supporting students to theorize, build, and improve ideas around their sustainability-related problem. However, we also found salient patterns in collaborative engagement across groups, suggesting that CCR development is non-linear with purposeful student activities. We then discuss the implications for CCR designs in practice.

Keywords: Collective cognitive responsibility, Knowledge building, Sustainability education, Student discourse.

1. Introduction

Research on computer-supported collaborative learning (CSCL) advocates for student-driven learning and the development of skills and dispositions beyond content knowledge gains. Knowledge Building (KB), a prominent CSCL approach, aims to promote cognitive collective responsibility (CCR) among students via collaborative discourse (Scardamalia, 2002). However, designs for CCR in practice and how CCR takes shape among learners are not well-understood (Cacciamani et al., 2021). To build on this line of inquiry, we explored the design and implementation of a student programme that promotes CCR through forming of a knowledge building community. The student Knowledge Building Design Studio (sKBDS; Yuan et al., 2023) is a holiday programme spanning two to three days, bringing students from different schools together to collectively tackle authentic real-world problems on sustainability and generate innovative solutions for knowledge advancement. The student activities were guided by KB principles and an online discussion tool called the Knowledge Forum was used to support collaborative discourse among students. In this study, we aim to understand the development of CCR from the students' contributions and their engagement through collaborative discourse across the phases of the sKBDS. This study contributes to the understanding of how CCR takes shape in student-driven learning designs.

2. Literature Review

Knowledge Building (KB) takes a knowledge creation view to support students in building innovative ideas through collective knowledge advancement (Scardamalia, 2002). KB supports students to engage in meaningful discourse and to build and improve ideas collectively as a community of learners (KB discourse). Students developed collective cognitive responsibility (CCR) which is "liken to a surgical team, members for example will

ideally share responsibility not only for carrying out the surgical procedure; they also take collective responsibility for understanding what is happening, for staying cognitively on top of events as they unfold.” (Scardamalia, 2002, p. 2). In classroom contexts, collective cognitive responsibility means that every student owns their learning and contributes according to their own knowledge and expertise to deepen ideas and advance knowledge as a community.

Researchers have investigated several design features using KB to promote CCR in collaborative learning. Zhang and colleagues (2009) explored a principle-based design (using KB principles to plan activities) supported by Knowledge Forum (online discussion platform for KB discourse) to support elementary students to contribute deep epistemic understandings as they explored real world problems (*real ideas, authentic problem*) and advance knowledge as a community. Hong and Lin (2019) looked into the use of KB scaffolds (sentence-starters) and they found deepening of collective idea-building on KF among elementary students. In higher education settings, Cacciamani and colleagues (2021) investigated the use of KB principles to promote CCR among undergraduates in an educational psychology course. They found that the participants showed different CCR development in different modes of KB discourse (i.e., blended, online, and face-to-face communication) after two weeks of discussion on course topics. Despite these efforts, the way CCR manifests in various settings or evolves over time in collaborative settings is not well-established. Hence it remains difficult to understand CCR designs (e.g. interpretation, measurement and conceptualization) particularly on scalable designs for practice.

Building on this line of inquiry, the notion of “infrastructuring” (Chen, 2024) offers new possibilities to explore and understand CCR designs. This “infrastructuring” view refers to an ongoing process of creating functional infrastructures for activities in a particular context, while infrastructuring itself means the dynamic *relational* proposition when adapting new elements into an existing infrastructure (ibid). From this perspective, designs for CCR may be approached in a more dynamic and flexible manner, meaning that design configurations may change overtime with new or emerging features (allowing for different or emerging components or activities). In this study, we report the sKBDS design, a short student programme (two or three days) with the flexibility to integrate different or emerging components (activities) overtime to support CCR development. Guided by existing literature, sKBDS incorporates KB principles to support planning of student activities (Zhang et al., 2009) and opportunities for blended (oral and online) discussions (Cacciamani et al., 2021). Unique to sKBDS is interest-based inquiry and interdisciplinary learning (on Sustainability), and a flexible design to consider evolving support tools such as learning analytics and facilitative strategies such as reflection discussions. Our research question is, “How does CCR take shape in sKBDS which is guided by a flexible design configuration?”

3. Methodology

3.1 Design of sKBDS

The design of the sKBDS can be described in four phases across two days (Table 1). Each phase was guided by a KB principle. The initial phase supported students to generate their sustainability problems and involved trigger activities and small group discussions. Students watched videoclips on sustainability issues and identified environmental problems of interest to explore. The second phase provided students with the space and time to generate ideas related to theories and solutions, and to address their problems through interactions with experts to gain knowledge on the *Internet of Things* and the use of new equipment such as sensors for data collection within small groups. The third phase provided students with support to test their solutions and improve their ideas on sustainability. Lastly, the final phase entails community feedback and reflection, where students shared their improved ideas and obtained insights from peers before they reflected on knowledge gaps for further exploration.

Table 1. Design for sKBDS and timeline.

KB phase/description	Student activities
(1) Sustainability problem generation (Real ideas, authentic problems)	- Trigger activity – exploring sustainability features on campus - Identify interest areas and formulate hypothesis/problems
(2) Generating ideas (theories and solutions) to tackle problem (Idea diversity)	- Introduce to Internet of things - Collect data for testing hypothesis - Refine problem statements supported by KB talk
(3) Improving on sustainability ideas (Improvable ideas)	- Collect data for testing hypothesis - Analyse/Discuss findings - Build/Improve artefacts (e.g. slides, prototypes etc)
(4) Community feedback and reflection on collective ideas (Rise above)	- Community sharing of ideas - Rise above with reflection

Note: Phase 1 – Day 1 (0900 to 1330hrs); Phase 2 – Day 1 (1330 to 1700hrs); Phase 3 – Day 2 (0900 to 1230hrs); Phase 4 – Day 2 (1230 to 1700hrs)

Throughout the program, student discussion was supported by the Knowledge Forum (KF) which is an online platform designed for knowledge building (Scardamalia, 2002). Figure 1 shows a view (discussion space) on KF where students interacted by posting, reading and building on each other's notes. In a KF view, each note (embedded box) represented a student's post and a build on was shown by another note connected by an arrow (sign indicates the direction of build on). When students clicked on a note, they were able to read the post that contains ideas, questions, explanations, or information (Figure 1). Embedded into the note is a set of customisable sentence starters, also known as KB scaffolds, which help to support students in building and improving ideas (e.g. 'My idea is', 'I need to understand', 'A better idea is', 'This idea does not explain', 'New information' and 'Putting our knowledge together').

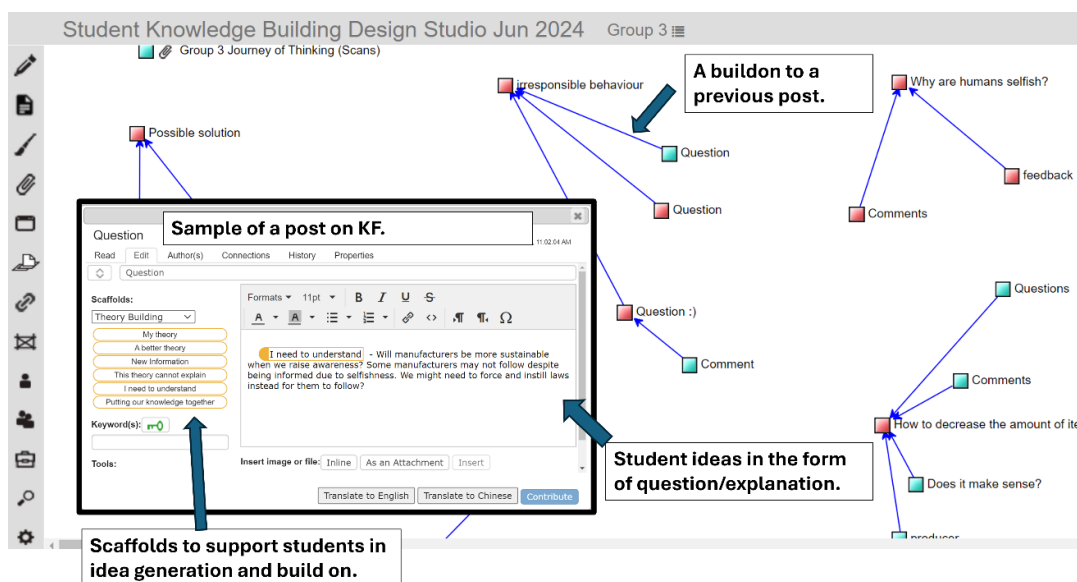


Figure 1. A view (space) on Knowledge Forum with student interaction.

3.2 Participants and data collection

A total of 36 primary students (ages 11 to 12) from 3 schools participated in the sKBDS in October 2023. The students formed 6 groups that worked on different sustainability topics of interest. The topics included wonderments about solar panels, coastal conservation, food waste, global warming, recycling, and pollution respectively. Students discussed and built on their ideas over the two days of programme, posting a total of 444 notes on the KF. In addition to the KF postings, each group also produced knowledge artefacts such as posters, presentation slides and prototypes to illustrate their ideas.

3.3 Analytical framework

To help us understand and see patterns from student build-ons, we used the Ideas-Building learning analytics embedded in KF (Figure 2) to generate social networks to assess student contribution and build-on patterns, filtered by discussion views, date, and time. The tool generates a network to represent the frequency of build-ons by each student (reflected by node size), as well as the interactions of posts among students who contributed to the discussion. The graphs also indicated whether students were collectively building on each other's posts and in which manner this was being conducted.

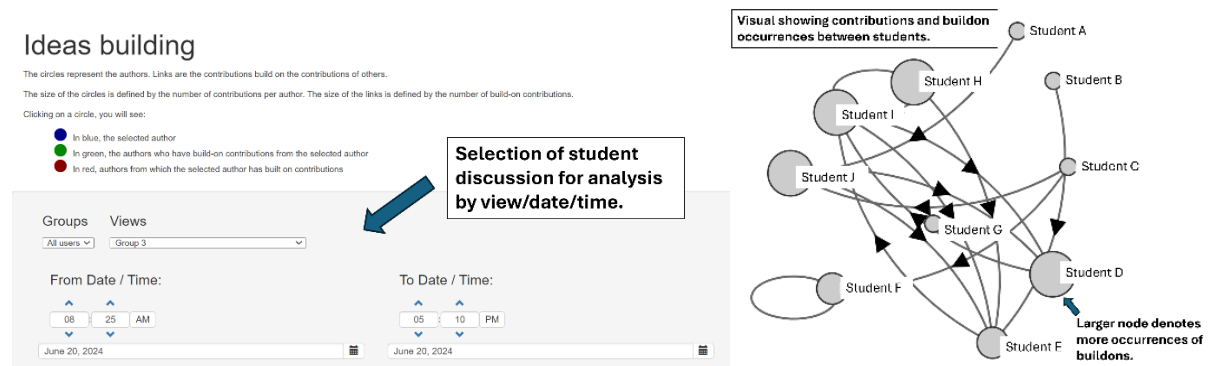


Figure 2. Ideas-building learning analytics (embedded in KF).

To further understand the quality of the student contributions, we used the coding scheme from Tao and Zhang (2018) to code for presence of theory building. Briefly, the scheme included five major categories of (i) questioning, (ii) theorizing/explaining, (iii) collecting evidence, (iv) referencing sources, and (v) connecting and integrating. The categories for questioning and theorizing include sub-categories to reflect the level of sophistication in the ideas. The description of these categories and sample illustration are shown in Table 2. This coding scheme enabled us to understand how students contribute collectively to the topic inquiry, which provided a measure of CCR. Two researchers separately coded one half of the pool of notes and reached an inter-rater agreement of 85%. One of the researchers then proceeded to code the other half of the notes for consistency.

Table 2. Coding scheme of categories and descriptions.

Theory building moves (code)	Description
Questioning (Q)	
(i) Factual question (Qf)	Questions asking for factual information
(ii) Explanatory question (Qe)	Questions in search of explanations
(iii) Idea-initiating wonderment (Qii)	Questions that search for general information about a theme-based area
(iv) Idea-deepening / Elaborating question (Qid)	Questions that search for deeper and more specific information on the basis of ideas discussed
Theorizing / Explaining (T)	
(i) Intuitive explanation (Ti)	An intuitive theory to explain certain phenomenon or issue based on personal experience using informal language
(ii) Alternative explanation (Tr)	A statement that suggests a possible different explanation in disagreement or conflict with existing explanation(s)
(iii) Refined explanation (Te)	An elaborated account of the specific processes and mechanisms using disciplinary concepts/terms
Collecting Evidence (CE)	A posting that describes experiments, and observations to either support or challenge an explanation
Referencing sources (RS)	A posting that introduces information from readings or websites and uses the information to deepen ideas and generate questions
Connecting and integrating (CI)	A posting that connects different ideas to generate a synthesis, summary, conceptualization, or integrated solution

4. Findings and Discussion

We first report the analysis of student contributions across the two days and then the results across phases to shed light on the development of CCR. Table 3 shows the frequencies of students' posts on KF, with each group posting between 50 to 71 notes except for one group (Group 6), where students posted 121 notes in total. In terms of buildons, the proportion

ranged from 28% (Group 3) to 59.5% (Group 6). The high proportion of 59.5% showed that students frequently read their friends' notes and added on their ideas.

Table 3. Contribution of notes from *SKBDS* participants.

Group	Notes Contributed	Buildons	Buildons %
G1	67	20	29.85
G2	71	28	39.44
G3	50	14	28.00
G4	70	33	47.14
G5	65	38	58.46
G6	121	72	59.50

Figure 3 shows the coding results of students' posts on KF. Within the questions categories, we noted that idea-initiating and idea-deepening questions were frequent in their discussions. An example of an idea-initiating question would be "How does the rising of the sea level affect the rivers like seen on the flume table?" Here, the inquiry by a student prompted the student group to think deeply about a larger problem in relation to the activities that they have experienced during the *SKBDS*. One example of idea-deepening would be "If trees do not [help to] decrease the temperature, then what other factors contribute to the temperature of surroundings?" Likewise, we noted that students were posting alternative explanations to bring in new perspectives to the discussion with refined explanations to elaborate on their ideas. These moves suggested that students were developing cognitive responsibility surrounding sustainability issues.

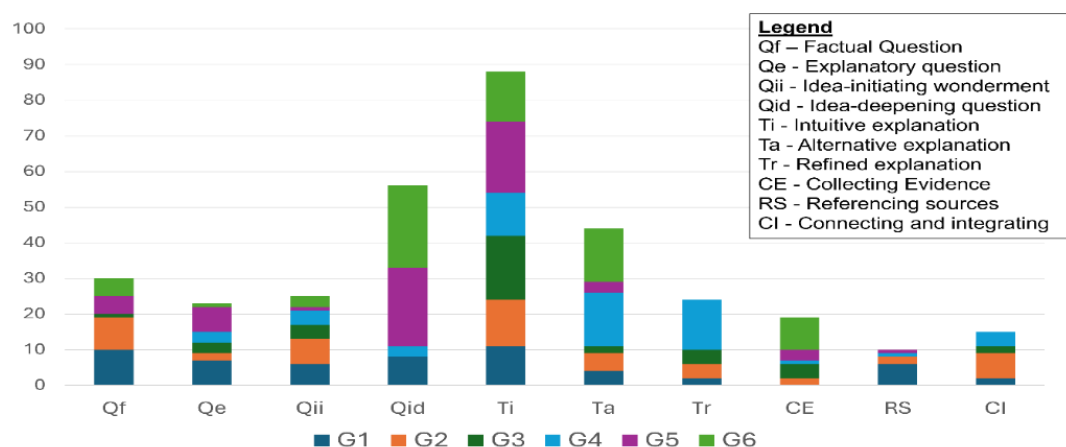
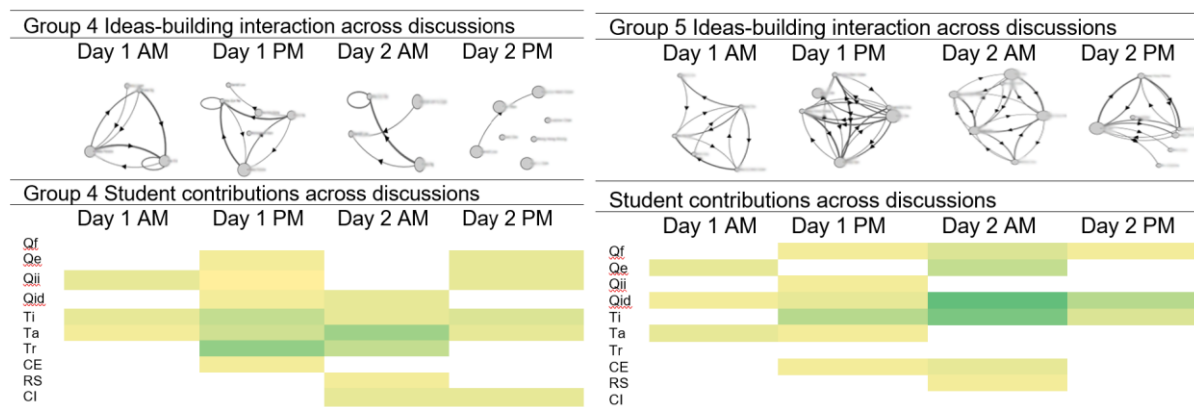


Figure 3. Overall contributions from students.

We further analysed this trend by groups and the different phases. Our preliminary findings showed that the engagement of theory building moves did not align with the phases. In fact, we noted contrasting patterns across two different groups. This is reflected using intensity of colors to reflect student contributions of respective theory building moves on a colour gradient, from colourless (no contribution) towards a darker shade of green, with each increasingly darker shade representing an increment of one level of contribution.

As shown in Figure 4, one group (Group 4) showed higher contributions of explanations and deepening of explanations between phase 2 and 3 activities, although they were more actively building on each other's ideas in phase 1 and 2. But another group (Group 5) showed higher contributions of deeper questions in phase 3 yet students in the group were quite actively building on each other's posts (from the ideas-building graphs). These contrasting patterns suggest that the development of collective cognitive responsibility is non-linear with intended student activities.



(Note: No colour - no contribution; Darker shade of green - each shade representing increment of one level of contribution)

Figure 4. Comparison of student contributions across two groups (Group 4 and 5)

5. Conclusion

In conclusion, our study offered a design of KB practice that teachers can adapt into classroom practice. Based on an “infrastructuring” perspective, the sKBDS design drew on an integration of KB principles, KF, oral discourse and reflection scaffolds to promote CCR. We have also incorporated emerging features such as a sustainability tour on campus to stimulate inquiry problems and interaction with experts to support the idea generation and improvement processes. The preliminary analyses in this study showed positive indications of CCR being exhibited, in terms of theory building moves that deepen the collective inquiry. However, the analyses also revealed that students’ development of CCR did not align closely with the design phases and differed significantly across several groups. Moving forward, we intend to analyse another set of data based on this design to validate our findings.

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