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Exploring Students' Epistemic Emotions in Knowledge Building Using Multimodal Data

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Abstract: Grasping students' emotions, especially those relating to learning, in a collaborative setting is no easy feat for teachers. The quality of collaboration comprises both visible behavior and emotion and the less visible emotional traits relating to engagement and motivation. Teachers often rely on their experience and intuition when it comes to these invisible traits. In this study, we collected multimodal data from a collaborative knowledge building classroom to analyze when and how students' emotions transpire during the working and improvement of ideas. Data included textual data, self-reports from surveys, interviews, and physiological data from face-to-face and online knowledge building discourse of 17 students in a 2.5-hour Social Studies lesson. We found shifts in epistemic emotions during idea improvement activities, and the students explained these shifts in understanding the discussion and engaging in idea-centric processes. We discuss findings for ongoing work to develop multimodal analytics for knowledge building practice.

Introduction

Multimodality refers to using multiple communication channels (modality) to acquire and relay information (Sinha et al., 2021). When students engage in collaborative discussion, they engage in multimodal behavior to demonstrate their knowledge or participate in discourse (Worsley et al., 2016). The use of multiple data streams from different sources to gain deeper insights for collaborative learning is rapidly growing. Recent developments have explored sensors to detect physical movement, eye-tracking devices to understand gaze and wearables to track physiological data. Data collected with these technologies allow researchers to gain insights into more tacit aspects of students' learning, such as emotions, cognition, motivation, and beliefs (Di Mitri et al., 2018). However, such work has mainly been confined to higher institution settings and specific collaborative tasks. In contrast, studies addressing the socio-emotional behavior of students in collaborative discourse in K-12 classrooms remain lacking. In this study, we build on this line of inquiry by investigating students' emotional and physiological behavior during Knowledge Building (KB) discourse (Scardamalia & Bereiter, 2003). We hope to understand primary school students' socio-emotional engagement during various idea-centric processes in KB discourse to support ongoing work in developing multimodal learning analytics for collaborative discourse in authentic settings.

Literature and background

Collaborative discourse in multimodal studies

Analyzing multiple data streams from different sources is a longstanding practice that can provide deeper insights for various educational purposes. Azevedo and Gasevic (2019) reported six studies that point to the necessary use of interdisciplinary, theoretically based and empirically derived approaches to collect, measure, and model multimodal data related to self-regulated learning data. Similar studies such as Furuichi and Worsley's (2018) examined participants' physiological responses (skin conductance response) concerning unique idea creation or secondary agreement to unique ideas in the group collaboration. Participants were found to be physiologically engaged (peaks in skin conductance) when posting new or unique ideas but were less so when they expressed agreement with ideas. This likely indicates that participants' physiological engagement tends to occur during critical junctures in group challenges, such as the initial and final stages of a challenge.

Other researchers sought different approaches to understand better collaborative learning, such as temporal analysis of multimodal data to predict collaborative learning (e.g. Olsen et al., 2020). By understanding multimodal data in a temporal manner, additional information and insights into collaborative learning processes can be obtained. In addition, the integrative use of multimodal data and learning analytics taps on the affordance of multimodality and move beyond a literal interpretation of data to extend current models and theories about complex interactions.

Emotion, learning and knowledge building

KB discourse is characterized by the generation of novel student ideas, questions, and challenging ideas, together with different perspectives that strive to improve the collective understanding of the problem. It focuses on a classroom discussion's generative and creative nature, moving away from a more typical and traditional classroom discussion that focuses on getting the single correct answer. Multimodalities is a potential approach to capture student behavioral engagement as they participate in an authentic KB classroom.

There have been attempts to investigate different facets of students' affective behaviors when they participated in KB discourse, but such studies are far and few in establishing a learning model. Zhu and colleagues (2019) study on Grade One and Two students' in KB discourse showed that epistemic emotions such as challenge and confusion could benefit collaborative discourse. Furthermore, these epistemic emotions correlated with high participation in the discussion and active reasoning and elaboration of ideas (Zhu et al., 2019). This work indicates an underlying rich layer of social and emotional changes that students experienced during KB discourse and further shows that this line of inquiry warrants more attention to consolidate its educational implications. The affective use of language has also been recognized to be of paramount importance to interactions and is a prerequisite of knowledge building and is sometimes considered a catalyst for higher levels of engagement (Polhemus et al., 2000).

Studies also have distinguished emotions relevant and specific to learning as epistemic and affective emotions. Epistemic emotions relate to knowledge and the generation of knowledge, including feeling challenged, confused, or frustrated (Pekrun, 2017). Affective emotions refer to the experience of emotions that can influence achievements or focus, with examples including happiness, sadness, or boredom (ibid). The relationship between epistemic emotion in collaborative learning is important and yet not well established. As the field of emotions and learning develops, we argue for a need to understand epistemic emotions in deeper and more active learning.

In this paper, we build on this inquiry by exploring epistemic emotions from primary students in relation to their participation in KB discourse in a social studies lesson. Using a multimodal approach, we also examine whether their physiological responses can provide further insights on emotional behavior during the KB discourse. We ask the following research question: "When and how do students experience epistemic emotions during KB discourse?"

Methods

Participants and settings

A total of 17 Primary Five (Grade Five) students and a teacher (experienced in knowledge building) participated in this study. The students attended a 2.5-hour lesson on a Social Studies topic ‘Man and Environment’. The students were randomly assigned to three groups, with each group given an authentic scenario that relates to residents living in different parts of the world (Mekong River, Anak Krakatoa, and Sarawak Rainforests). Individual group was tasked to discuss and find solutions to existing problems (habitat loss, active volcano, and deforestation) that threaten residents' livelihoods and environments.

Collection of multimodal data

We adopted the setup as shown in Figure 1 to collect multimodal data, using the following: A 360-degree camera to capture students' physical interactions in the group collaboration; A multichannel audio recorder with supporting lapel microphones to record individual students' speech; An Empatica E4 wristband that each student wears to record their physiological data; and a GoPro camera to capture whole-class interactions.

Figure 1

Equipment and sensors used to record multimodal data during the lesson

Data analysis

We analyzed the following sets of data to answer our research questions: (1) Teacher's lesson plan, (2) students' emotion survey, (3) Knowledge Forum (KF) notes (similar to online forum postings), (4) physiological data, and (5) student interviews.

(1) Teacher's lesson plan: In this study, we used an online discourse platform (Knowledge Forum; KF) and analyzed the activities on the platform with respect to the lesson progression that the teacher planned. We examined the lesson plan to identify the different types of KF activities used for engaging the students as shown in Table 1.

Table 1

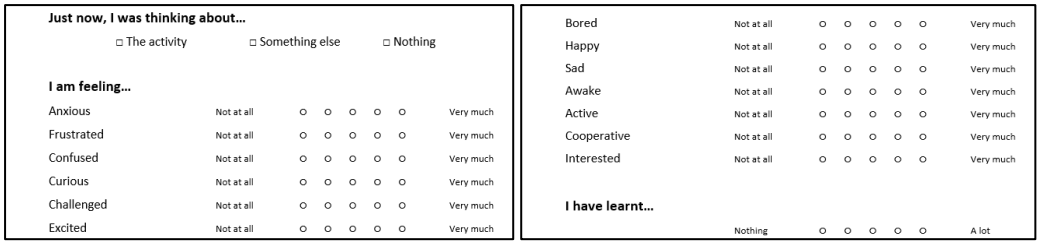
Analysis of KF activities from the teacher's lesson plan

Phase of lesson	Teacher's instructions and class activities	Students' KF activities
Activating Activity	● Students played the roles of locals in three Southeast Asian areas (Sumatra Rainforest, Mekong River, and Anak Krakatoa). ● Students introduced to the KB task, which is a Town Hall discussion anchored on the question: "Should our community stay or relocate from our area?"	No KF activities recorded.
Idea Generation	● Students discussed the anchor question in their respective groups. ● Students posted notes on KF stating their stand and supporting reasons.	Discuss and post different perspectives (stand) with reasons on KF
Idea Improvement – Build On	● Students discussed and built on their peers' ideas on the Knowledge Forum using build-on scaffolds. ● The teacher used learning analytics such as word clouds and an in-built Scaffold Tracker to conduct a meta-discussion and highlight value-adding contributions.	Read and build on groupmates' viewpoints, such as clarifying, inquiring, or proposing new elaborations.
Idea Improvement II – Rise Above	● The teacher introduced a Rise-Above scenario: Students took on newer roles as community representatives to potentially implement solutions to the respective area's issues.	Negotiate as a group, weighing the pros and cons of different solutions to develop a solution.
Idea Assessment	● Students consolidated their problems and solutions that were then shared with the class for comments and suggestions.	Post synthesis of group ideas and peer feedback for improvement.
Reflection	● Students responded to three reflection questions on KF.	Post reflection on KF

(2) Students' emotion survey: We constructed an Epistemic Emotion Survey (EES) to capture students' emotions of the moment. The EES explored a range of affective emotions (excitement, boredom, happiness, sadness) and epistemic emotions (anxiety, frustration, confusion, curiosity, challenged) (Pekrun et al., 2017). The survey approach was intended to provide a relatively reliable way of knowing what students were feeling at specific time junctures of the study. It was inherently difficult to visualize or interpret emotions from facial expressions, particularly epistemic emotions that were primarily internal to the student. Students did the first scoring at the start of the lesson. On a 5-point Likert scale, scores can range from "not feeling" an emotion at zero to feeling the emotion "very much" at five. This first emotion data point provided us with a baseline for comparing students' feelings throughout the lesson. The students then continued to respond at planned junctures between significant KB activities throughout the lesson (a total of 11 junctures). We collated students' scores and synchronized the data to the timeline of KF activities

Figure 2

Top half (left) and the bottom half (right) of the Epistemic Emotion Survey used to capture students' emotions.



(3) KF notes: We analyzed the semantic patterns from student notes using four levels of semantic patterns adapted from Zhang et al (2009). The levels (codes in parentheses) included fact-seeking question (Q1), explanation-seeking question (Q2), explanation with simple points or simple statement without elaboration (E1), and explanation with elaborations or rise-above (E2). We coded a total of 161 notes. Two researchers independently coded the notes and reached a strong inter-rater reliability (above 85%).

Table 2
Description and examples of semantic patterns of KF notes (Adapted from Zhang et al., 2009)

Codes of semantic patterns	Description/Examples
Fact-seeking question (Q1)	Questions that elicit factual information, using when, where, or who. E.g., "Where do you want to go?"
Explanation-seeking question (Q2)	Questions that inquire into relations between facts elicit elaborations, such as why, how, and what. E.g., "Why should we be affected by other people living in the modern world?"
Explanation with simple points/Simple statement without elaboration (E1)	Simple statement without elaboration. E.g., "You are contradicting yourself. These are the exact reasons why we should move."
Explanation with elaborations/rise-above (E2)	Statement with elaborations to provide reasons, relationships, or synthesis of ideas. E.g., "We don't really have a government. Without a government, there is no law, no order. And with a government, we suffer under a dictatorship. People who are weaker will abuse power."

(4) Physiological data: We processed the data from the Empatica wearable using the software *Ledalab,* to generate graphical output of skin conductance response (SCR) from individual students. SCR is a measure of how well the skin conducts electricity when an external direct current of constant voltage is applied in micro Siemens (μS). A peak in the SCR indicates a physiological arousal experienced by the student at that moment in time.

(5) Interviews: We conducted individual interviews with all students to gather more information about their responses on the emotion survey. During the interviews, students were shown short video clips of their discussions and the KF notes that were posted during the lesson as part of stimulated recall. The students were then invited to share their reasons for the reported emotions at different lesson segments. We subsequently used the open coding approach to discover preliminary themes from the students' reasons and reported emotions.

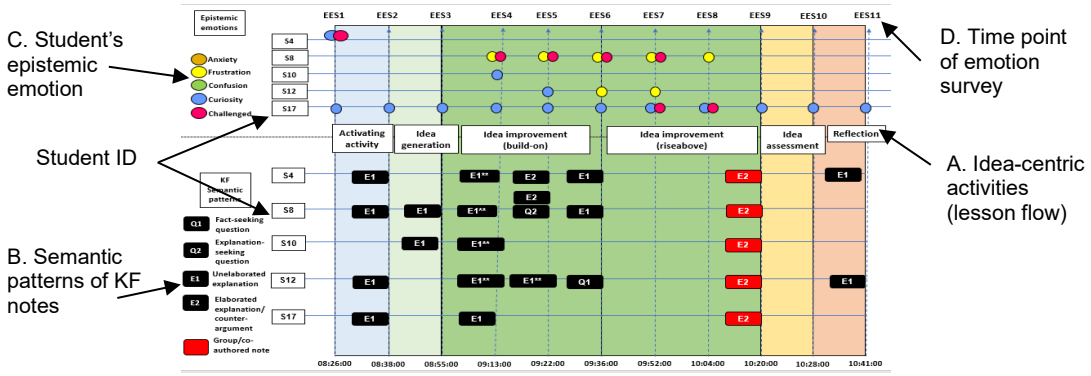
Organizing multimodal data for comparison

To visualize patterns from the multimodal data, we compared the analyses from the emotion surveys and KF notes, with the analysis of KF activities and presented them in a graphical manner. Figure 3 provides a sample illustration. First, the timeline of KF activities served as a baseline for comparisons with other modalities (point A). Second, the semantic patterns of the students' KF notes were matched with the timeline (point B). These semantic patterns were sampled at every 15-minute interval of the lesson, with each box in the graph representing a contribution from the student and the corresponding semantic pattern. For example, a box with Q1 and E2 indicates that the student has contributed a fact-seeking question and explanation with elaboration in the note.

The colored codes differentiate between an individual or group note. By having this comparison, we can infer the quality and extent of students' participation in their collaborative discourse. Third, to understand students' epistemic emotion during the discourse, the emotion survey scores were matched to the timeline. Each circle in the graph represents an emotion experienced by the student with a score of 3 or more (point C). These circles are again color-coded to represent different emotions. Last, the timing when surveys were conducted are also provided as part of axial reference (point D). This comparison helped us to relate instances of high/low collaborative discussion with corresponding indications of students' emotions throughout the different KB lesson components.

Figure 3

Representation of multimodal data (emotion survey and analysis of KF notes) in small group discussions with respect to the phases of idea-centric activities and the time-point of emotion survey



Results

Answering "when do students experience epistemic emotions during KB discourse?"

Our analysis revealed patterns of higher frequency of epistemic emotions when students engaged in important idea-centric practice processes. These are shown in Figures 4a, b, and c, emotions are highlighted (dotted-box in the upper half of the figures), with students reporting feeling more on epistemic emotions during certain phases of KF activities.

To further illustrate this with a group, in Figure 4a, frustration, confusion and curiosity were observed from the students at time points 4 to 8, suggesting that KB activities of idea improvement phases (prior and succeeding these survey time points) played an important role in providing stimuli that influence the students' emotions. This pattern appeared consistent across all three sampled groups. In addition, KF activities were also found to correspond with frequent reports of epistemic emotions that were characterized by active student engagement of questioning and explaining ideas. Referring back to figure 4a, a relatively higher contribution of questions (Q1, Q2) and explanations (E1, E2) were observed during the idea improvement phase, with semantic patterns highlighted using the dotted-box in the bottom half of the figure. This pattern was also noted in the other student groups, which likely meant that students' emotional engagement was heightened when they engaged in more questioning and built on ideas in the KB discourse.

Figure 4a

Students' self-reported emotions compared with online discussion for the first student group.

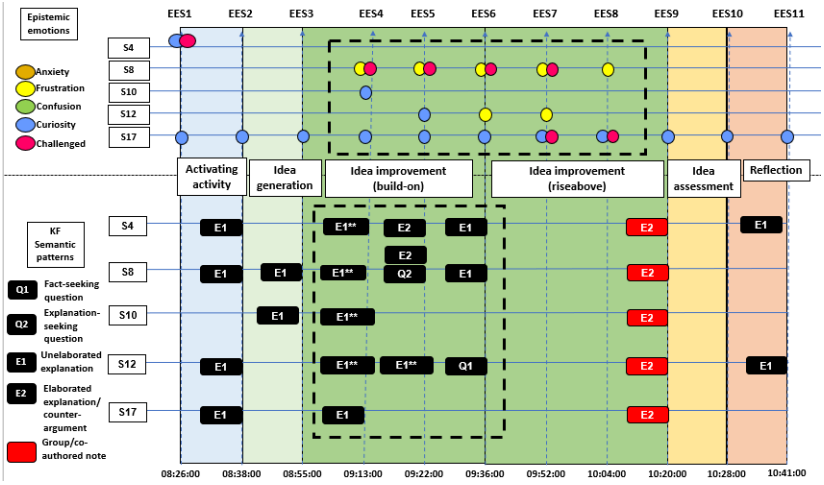


Figure 4b

Students' self-reported emotions compared with online discussion for the second student group.

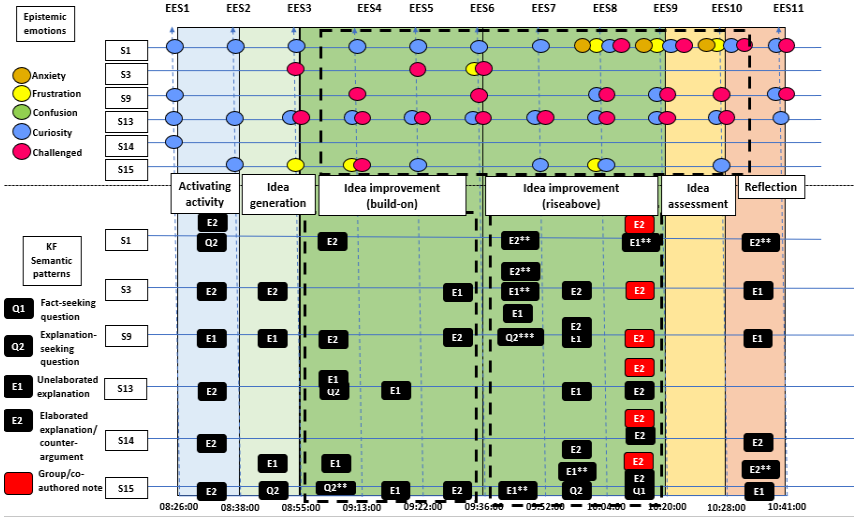
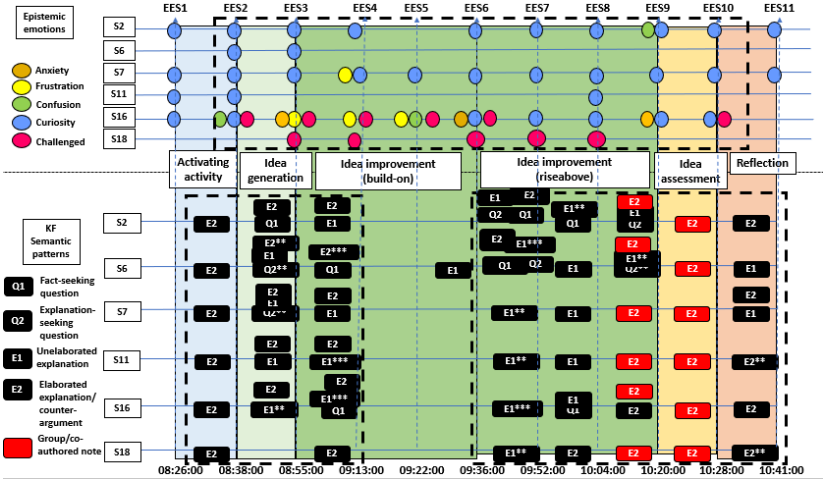


Figure 4c

Students' self-reported emotions compared with online discussion for the third group.



Answering: How do students experience epistemic emotions during KB discourse?

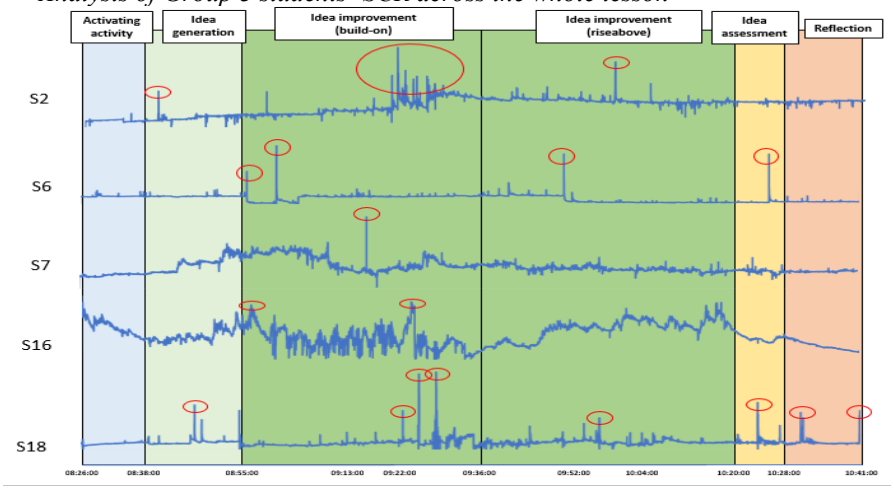
This question is answered in two parts. First, the time-points in the lesson where individual students reported a change in epistemic emotions were identified from the surveys by filtering self-reporting emotion survey scores that increased by more than two on the Likert scale. Interviews were then conducted within a week of the lessons to discover possible underlying reasons for these changes.

We found that students' reasons for the change in epistemic emotion were related to the following three categories: (1) Students' ability to comprehend and understand the discussion, (2) Idea-centric processes, and (3) about the topic that was being discussed. Students reported more nuanced reasoning for the epistemic emotions that arose from idea-centric processes. Specifically, students articulated confusion when they were unsure about their friends' opinions; when the group has conflicting ideas; when they thought the proposed ideas were not feasible; and when the group started looking into unimportant ideas. Similarly, we noted that curiosity was more commonly triggered by students wanting to find out more about the problem at hand. Curiosity was piqued in idea-centric processes such as: when new ideas that require more explanation emerged; when the ideas were not wholly justified; when students struggled to agree with one another and their arguments.

Second, apart from the analysis of interviews to explain students' change in emotions, we looked into the change in the physiological data (skin conductance) at specific time points and observed corresponding physiological responses. Analysis of physiological data from Group 3 showed common peaks in SCR during the idea improvement (build on) phase, as shown in Figure 5.

Figure 5

Analysis of Group 3 students' SCR across the whole lesson



Discussion and conclusion

This mixed-method study is focused on tackling the unpredictability of KB processes. We have only worked with a relatively small sample size and currently are collecting more data and consolidating the design of an MMLA Programme that can handle data sets in a more sustainable and scalable manner. Nevertheless, the current findings from this study support those in the existing literature that students experience epistemic emotions when they actively engage in collaborative discourse to work on their ideas.

This study has explored a range of epistemic emotions, including frustration, curiosity, anxiety, confusion, and challenges. Our work shows that students not only experience a wide range of epistemic emotions during collaborative discourse, but such emotional behavior appears more heightened when they engage in sense-making and negotiation of their ideas. This claim was supported by: (1) the interview data in which students explicitly referenced their emotional changes to the idea-centric processes such as dealing with conflicting and improving on new ideas on KF, and (2) the physiological results, which also detected changes in SCR during such phases. We are cognizant that our findings are limited to small sample size. However, this study should show that such a naturalistic study of students' emotions in a complex learning environment can illuminate the intersection between emotion and learning and provide a forward move towards the design of more systematic and rigorous studies to impact practice.

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