

Emotional and Cognitive Affordances of Collaborative Learning Environments

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Abstract: Collaborative learning involves intricate interactions in which students participate in cognitive activities within social-emotional environments. Cognitive interactions mediate knowledge sharing, construction, and creation, while social-emotional interactions shape student perception of community climate and influence their emotional expressions, which, in turn, have a significant impact on their cognitive interactions. Although research has consistently found that social presence and student-student interaction has a positive influence on students' learning through emotional engagement, subject-based teaching remained largely more of cognitive activities. Teachers tend to treat lessons that heightened social-emotional aspects separate from subject-based lessons. This symposium brings together an international group of scholars to present recent studies on emotion and cognition in collaborative learning environments. Methods, such as self-report, video observation, affective state detection using FACET, and machine learning models, were adopted to investigate students' emotions. The results collectively suggest that these methods indeed served to uncover students' emotions; emotions such as joy/enjoyment/happiness, confidence, and surprise were associated with students' knowledge building progress; and that students' online interactions had a high impact on the emotional and linguistic tone of learners. The symposium aims to discuss the theoretical, practical and policy implications of these studies on collaborative learning.

The overall focus of the symposium

Collaborative learning describes a situation where particular cognitive and social-emotional forms of interaction among people trigger learning mechanisms (Dillenbourg, 1999). Cognitive interactions mediate knowledge sharing, construction, and creation. Social-emotional interactions shape student perception of community climate and influence their expressions of emotions (Bakhtiar, Webster, & Hadwin, 2017; Järvelä, Järvenoja, Malmberg, Isohätälä, & Sobocinski, 2016). In previous studies, achievement emotions such as anxiety and enjoyment were the most researched emotions (Loderer, Pekrun, & Lester, 2018). However, epistemic emotions such as confusion, curiosity, and surprise, which tend to arise during cognitive activities and the learning generation process (Pekrun & Linnenbrink-Garcia, 2012, 2014) and social emotions triggered by students' interactions in collaborative learning have been rarely researched (Loderer et al., 2018). The study of how students' social and epistemic emotions interplay with students' knowledge construction or knowledge building process is in its infancy. Presentations in this symposium have responded to this question in different learning contexts, using different methods and from different perspectives.

Multimodal data can be collected and analyzed using different techniques—including sentiment analysis, facial expression recognition, self-reports, and biosensors—to measure emotions (e.g., Arguedas, Daradoumis, & Xhafa, 2016; Koolagudi & Rao, 2012; Loia & Senatore, 2014). Researchers have explored ways to study social-emotional interactions between students (e.g., Isohätälä, Näykki, & Järvelä, 2019; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). Despite these developments, real contextual constraints in collaborative learning environments (e.g., multiple students, movements during activities) may limit the use of the technologies to

measure emotions. The five studies included in this symposium will present different methods used to uncover students' emotions in collaborative learning contexts. The pedagogical implications of these findings are critical in translating this research to impact classroom practice.

The overarching points illustrated by the collective work

This symposium aims to achieve the following goals:

1. Enhance our awareness of cutting-edge studies on emotion and cognition in collaborative learning environments.
2. Discuss and reflect on the reliability, applicability, and possible limitations of the methods adopted.
3. Advance the theoretical understanding of relations between emotions and cognition.
4. Discuss the practical and policy implications of these studies, such as how to design supportive emotional and cognitive learning environments to foster productive knowledge building and student well-being.

The significance of the contributions

The five studies in this symposium represent initiatives of understanding how to uncover students' emotions and how emotions interplay with students' knowledge building processes in classrooms, museums, or fully online platforms. Methods, such as self-report, video observation, affective state detection, and machine learning models, were adopted to investigate students' emotions. The results collectively suggest that these methods helped uncover students' emotions; emotions such as joy/enjoyment/happiness, confidence, surprise were associated with students' knowledge building progress; and students' online interactions had a high impact on the emotional and linguistic tone of learners.

Furthermore, these studies open areas for further inquiry and provide practical implications-regulating students' socio-cognitive-emotional dynamics to foster productive knowledge building and emotional well-being. For instance, Teo and Ng suggested that Knowledge Building students seemed to be developing some (meta) emotions that had helped them to cope with otherwise a stressful learning experience. In Badron, Teo, and Tan's study, the students themselves indicated that more opportunities for group work, longer thinking time, and usage of videos as additional resources would enhance their learning experience.

How the collective presentations contribute towards the issues or points raised

In this symposium, an international group of scholars will present recent studies on emotion and cognition in collaborative learning environments, ranging from classrooms to museums, from physical spaces to online communities, and across Western and Asian societies. Also, diverse methods such as speech emotion analysis, data mining, qualitative ethnography, and grounded methodology have been adopted in different studies. Collectively, these studies found that (1) collective reflection design in knowledge building contributed to students' increased enjoyment, curiosity, and surprise; compared to enjoyment, confidence was more highly associated with students' elaborated explanations and proposals of inquiry directions; (2) knowledge aggregation was followed by a higher joy score; (3) as students entered into the 'more difficult' knowledge building activities, more students reported that they felt happy about their knowledge building experience although fewer students reported they wanted to know more about the topics; (4) cogenerated dialogue helped uncover students' emotion engagement and brings about awareness of the potential emotion climate experienced by most students in the class; and (5) during fully online learning, various types of interactions had a high impact on the emotional and linguistic tone of learners.

Structure of the session

This symposium includes five studies on the relations between emotion and cognition: (1) Collective Reflections, Knowledge Advancement and Emotional Well-being of Young Students; (2) Associations between Emotion and Moments of Learning Studied through Dialogue and Affective State Tracking; (3) Understanding the Academic Emotion of Students in the Knowledge Building Process; (4) Exploring Student's Emotion Engagement and Mediating Change through Cogenerative (cogen) Dialogue; and (5) Towards Understanding Emotional Presence in An Online Community of Inquiry: A Machine Learning Approach. We will use the following session organization:

1. Welcome and introduction by session chairs (3 min)

2. Five presentation and short questions and answers between presenters and audiences (11 min for each presentation, in total 55 min)
3. Synthesis and discussions of common interests and issues by the discussant (Dr. Earl Woodruff) (15min)
4. Open discussion with the audience (17 min)

(1) Collective reflections, knowledge advancement and emotional well-being of young students

Gaoxia Zhu, Marlene Scardamalia, Raadiyah Nazeem, Zoe Donoahue, Zhixin Lai, and Leanne Ma, University of Toronto

Knowledge Building is a pedagogical approach that emphasizes students as epistemic agents taking high-level collective responsibility to work on real ideas/authentic problems as they understand the world (Scardamalia & Bereiter, 2014a). The control-value theory assumes subjective controls and values are specifically relevant to achievement emotions (Pekrun, 2006). Subjective control refers to an agent's perceived causal influence over actions and outcomes (Skinner, 1996). Subjective value describes how important and attractive certain actions and outcomes are to an agent (Pekrun, 2006). Theoretically, Knowledge Building would contribute to students' positive emotions as it emphasizes student agency and values their authentic inquiry directions. Collective reflections on the status of community knowledge and promising future directions for inquiry have shown effectiveness for advancing community knowledge (e.g., Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015; Zhang et al., 2018). This study investigated how students' increasing epistemic agency and collective responsibility for their work influenced their knowledge building and epistemic and activity emotions. We turned over more epistemic agency to 22 grade 2 students by involving them in collective reflections. Furthermore, students proposed future inquiry directions shaped the subsequent inquiry. Specifically, we aim to answer three questions:

1. How does students' engagement in collective reflection (meta-discourse) influence their activity emotions and epistemic emotions?
2. What is the association between students' activity emotions and epistemic emotions and their idea improvement?
3. What are students' emotional connections to their individual and community idea improvement?

The students explored salmon and related topics for four months. Extensive face-to-face videos and online work were collected. The students were interviewed on their feelings around ideas they had improved and ideas that were rarely responded by peers or teachers at the end of year 2. Using grounded theory (Glaser & Strauss, 2017) and achievement-related emotions (Pekrun, 2016; Zhu, Xing, Costa, Scardamalia, & Pei, 2019), a multi-faceted (words, gestures, facial expressions, voice, emojis) coding scheme was used to analyze emotions as idea improvement proceeded. The inter-rater reliability between two researchers regarding emotion coding was 87.6%. Transcripts of face-to-face videos and online notes were coded based on a coding scheme that identifies moves such as explanation-seeking questions, explanations, and integrating ideas (Zhu et al., 2019) to show idea improvement moves as participants take speaking turns or write online. The inter-rater reliability for two researchers regarding idea improvement coding was 76.7%. Then we conducted a correlation between students' emotions and idea improvement types.

The results suggested that the collective reflection design contributed to students' increased enjoyment, curiosity, and surprise as well as greater agency and responsibility. Compared to enjoyment, confidence was more highly associated with students' elaborated explanations and proposals of inquiry directions. Enjoyment was mostly associated with proposing ideas, improving the life cycle of Atlantic Salmon, designing salmon habitats, having salmon in the classroom, and learning new things. The participants felt good about community reflection and thought it helped their learning. Some students enjoyed the process and the result of improving the diagram for public good. The students expressed concern for those who received no response or no answer to a question. The missing stages in the salmon life cycle diagram and the usability of the drawing tool in the Knowledge Forum triggered several students' negative feelings. Students might feel challenged because they could not explain their ideas.

Theoretically, through qualitative and quantitative analysis, this study developed a model between epistemic emotions and the knowledge generation process. Further research will be focused on regulating students' activity and epistemic emotions in collaborative inquiry learning to test and refine the model. Practically, this

study suggests that engaging students in collective reflections on what they have learned and where their inquiry should go opens new opportunities to sustain their Knowledge Building and benefits their positive emotions.

(2) Association between learning and emotion: A study of dialogue and affective state

Kit Martin, Northwestern University

Emotional states, tracked through facial expressions, interact with certain cognitive states to afford learning (D'Mello & Graesser 2012). D'Mello and Graesser studied the role of surprise and joy as indicators of a student transitioning into or out of a moment of confusion. While still discussed in terms of short term cognitive gains, the model implies that examining affective states can be instrumental for better understanding learning. Research on neurobiological parts of memory shows that emotionally arousing stimuli consolidate and preserve more often over the long term (McGaugh, 2003; 2006). Both positive and negative emotions are associated with memorable moments controlled selectively within the basolateral amygdala (McCaugh, 2004). The brain region regulates the consolidation of memory for various experiences through projections from the amygdala to many other regions involved in storing newly acquired information stored in engrams (McCaugh, 2006). Therefore, we hypothesize moments of peak arousal are correlated with moments of peak learning.

In this study, we track knowledge building and emotional arousal while participants use a tabletop, knowledge-construction game built for a museum (Martin, Horn, & Wilensky 2018, 2019). The activity is a constructionist microworld (Edwards, 1995; Papert, 1980). In the activity, participants play against each other, and build theories, observe how ant colonies self-organize and use theory to increase colony population and secure food resources. During the activity, students develop theories of how to increase ants' population and adjust ants' adaptations. They then dynamically test their theories as a group with the computer (Martin et al., 2019). We investigate how and when arousal and knowledge construction interact.

Similar to Worsley, Scherer, Morency, and Blikstein (2015), we segment multimodal data streams to monitor emotions, whenever the user has a change in their most probable facial expression. We particularly studied moments of peak arousal. We used Social Signal Interpretation (SSI) (Wagner et al., 2013) to collect synchronized video and audio data. We processed this data into transcripts for Constructivist Dialogue Mapping (Martin, 2018) and individual videos of participants for affective state detection in FACET.

We track student ideating and theorizing using Constructivist Dialogue Mapping (Martin, 2018), a type of concept mapping (Miles, Huberman & Saldana, 2014) that we developed. We qualitatively code what rules each participant thinks each agent in the microworld can perform, and the properties that facilitate or inhibit those functions. We find museum visitors elaborate their understanding through the experience (Leinhardt & Crowley, 1998). We time-stamp when each participant introduces each idea, share ideas, and adopt theories. This allows tracking participants' understanding of the microworld. We then correlate each participants' affective state, with their knowledge gain. We used automated Facial Analysis (AFA) to code the affective states (Cohn & De la Torre, 2014). This allows us to see when arousal correlates with learning. We find 'windows of learning' where at the local scale, knowledge aggregation is associated with a higher joy score. This finding encourages us to investigate moments preceding and postceding participant's performance of affective states, such as joy, to find moments of knowledge construction, which will allow data stream segmentation.

(3) Understanding the academic emotions of students in the knowledge building process

Chew Lee Teo, Nanyang Technological University and Andy Ng, St Hilda's Primary School

Knowledge Building practice, also termed as idea-centric practice, focuses on getting students on a collective idea improvement trajectory. It proposes that students are capable of creating new understanding collectively. Teachers who adopt the knowledge building approach are mostly teachers convinced of the positive impact of students' engagement and motivation in class and the students' cognitive activities. It seemed that these positive students' emotions quite naturally translates to sustained positive outcomes in the academic areas (Hu et al., 2007). However, we also noted a trend among the practice of some of the experienced KB teachers, that they tend to rush through the knowledge building activities, or activate a premature closure of students' knowledge building effort when the teachers sense that the students' interest is dwindling. Most of these occasions, students have reflected in the interview that they wished they could have more time to rebuild their prototype or rework their presentation but they were told to stop. These trends of knowledge building practice warrant a closer look at the relationship between students' emotion and their engagement in the knowledge building in subject-disciplinary learning.

Especially when current school practice tends to manage students' emotions as a separate domain (e.g., student counseling, home room) from subject disciplinary learning. This study uses a self-reporting mechanism to understand students' emotions at different stages of the knowledge building process and analyze the relationship between their feelings and their contributions in class.

Twenty-six 11-year old students of similar abilities in a knowledge building class worked on an online discussion forum, Knowledge Forum (KF, Scardamalia & Bereiter, 2014b) that archived their contributions to the discussion. These lessons were designed with four types of knowledge building activities: (1) Asking questions; (2) Challenging ideas; (3) Thinking Further; and (5) Rise-above (presumably with increased difficulty). After each knowledge building activities, students self-reported, through an embedded google-form on knowledge forum, their feelings, their sense of value to the community, and the usefulness of their contributions.

The results show that as students entered into the 'more difficult/advanced' knowledge building activities such as "thinking further", and "Rise-above", the percentage of students who felt excited dropped from 34.6% to 28%, but the percentage of students that they were happy increased from 50% to 60%. The percentage of students who felt that they wanted to know more about the topic increased from 36 to 52%. The positive emotion of students in this "more difficult" knowledge building activities was substantiated by qualitative responses such as, "The conversation was becoming an online argument, and I was excited to defend my view and convince some others to stay near the Mekong river", "although there (are) a few posts criticizing my points, I still felt that they were all I could think of at that time, I felt ok". We also noted a range of positive emotions from those who are more central to the discussion on KF, such as "There started to be heated arguments among us, and I felt that it could have helped me to learn more interesting facts while the argument was going on" and "The ideas provided had varied yet more than at the previous time and I was very curious about where they came from.", "if I were not valued, nobody would waste their time criticizing, so it is ok."

The students enjoyed the varied ideas, even those whose ideas were criticized. We also noted that several students could give detailed accounts of why they were feeling a certain way. We need to explore further as it seemed to imply that these Knowledge Building students seemed to be developing some (meta) emotions that have helped them to cope with otherwise a stressful learning experience.

The students' accounts enabled us to have a deeper understanding of the ups-and-downs of the Knowledge Building process that otherwise would have been misunderstood by teachers as lack of interest or road-blocks that might lead to premature closure of the knowledge building work. If this premature closure is not tackled productively, we might end up with students who would perceive knowledge building as merely a brainstorming exercise, never getting a chance to work critically with their ideas. The teacher, too, reflected that although he noticed that the students were struggling at the more difficult knowledge building activities such as think further and rise-above, he also noted that the students remained quite positive. He felt that if he had been heightened to the students' emotional states and provided a sneak preview of how they were feeling through the survey, he might have concluded the inquiry earlier and facilitated a more teacher-centric discussion.

(4) Exploring student's emotional engagement and mediating change through cogeneratedative (cogen) dialogue

Mohamed Faizal Bin Badron, Tang Wee Teo, and Aik Ling Tan, Nanyang Technological University

This pilot study presents findings and analysis of student's emotional engagement during a lesson before cogen dialogue and leverage on the findings to mediate change to teacher's instructional methods in the subsequent lesson. Cogen dialogue sessions served as a platform for students, teachers, and researchers to discuss the common shared experience in the classroom and reach solidarity for change to enhance teaching and learning practices in the classroom. This study focused on how cogen dialogue could be used as an approach to (1) explore student's emotional engagement during a lesson and (2) mediate change to teaching instructions in the next lesson?

One of the tenets of cogen dialogue, which emphasized the "no voice is privileged" (Murphy & Carlisle, 2008, pg. 495) principle, provides students with the voice to articulate their challenges in learning. Numerous studies (e.g., Baker, 2010; Emdin, 2011; Tobin, 2001; Tobin & Roth, 2005) have reported the success of cogen dialogue in mediating change in areas such as cultural differences, teaching praxis, students' behavioral issues and transforming teachers' identities. However, there is a dearth in exploring the potential of cogen dialogue in discovering students' emotions as a catalyst for change.

The study was conducted in a local secondary school in Singapore with a Physics teacher and one of his students. I have adopted a case study approach, and I was involved as one of the researcher participants in the cogen dialogue. Drawing from video recordings in the classroom, I identified vignettes of interest based on the student's gazes and gestures. During cogen dialogue session, the vignettes of interest were played, and the

participants engaged in interpretive analysis to make sense of the gazes and gestures made during the lesson with the emotional engagement of the student.

Results from this pilot study have shown that through cogen dialogue, student's emotional engagement could be elicited and analyzed in greater depth based on the gazes and gestures captured. The interpretive analysis brings about awareness of the potential emotional climate experienced by most students in the class. The product of the cogen dialogue discussions led to solidarity towards change in the subsequent lesson. Among the changes suggested by the students were: (1) more opportunities for group work discussion during lessons, (2) longer thinking time, and (3) the usage of videos as additional resources to the diagrams in the textbook to enhance the learning experience. In addition, through cogen dialogue discussions, the physics teacher had the opportunity to share the constraints to some of the changes suggested by the students.

The significance of this study is the contribution towards cogen dialogue literature on the usage of cogen dialogue as a platform to elicit emotions that served as a basis for change. Through cogen dialogue, non-verbal cues such as gaze and gestures which could otherwise be overlooked were expounded. The efforts to map out changes in subsequent lessons seek to improve the learning experience of the students in terms of both performance and emotions.

(5) Towards understanding emotional presence in an online community of inquiry: A machine learning approach

Preeti Raman and Jim Hewitt, University of Toronto

Online learning is growing rapidly, leading to an urgent need to research methods that help provide temporal, spatial, and intellectual support to learners (Artino & Jones, 2012). Understanding the students' emotions is critical to provide such support promptly (Wosnitza & Volet, 2005; Ware, 2004). Moreover, research in cognitive psychology suggests that the emotional state of the learner should be viewed as a starting point for education (Damasio, 2000; Gray, 1990; Lazarus, 1982). They can impede or enhance the learning process (Pekrun, Goetz, Titz, & Perry, 2002); thus, it is important to understand student emotions in online learning contexts. In this study, we performed a psycholinguistic analysis on student discussions to understand both linguistic and emotional tones in an online learning environment to inform affective design of online courses.

The Community of Inquiry framework (CoI) is commonly used as a tool for research into online learning (Garrison, Anderson, & Archer, 1999, 2010). It identifies cognitive presence, social presence, and teacher presence as key elements to a successful online learning experience. However, recent research suggests the addition of emotional presence as an additional CoI element (Cleveland-innes & Campbell, 2012; Stenbom, Hrastinski, & Cleveland-Innes, 2016). Cleveland-Innes and Campbell (2012) defined emotional presence as "the outward expression of emotion, affect, and feeling by individuals and among individuals in a Community of Inquiry, as they relate to and interact with the learning technology, course content, students, and the instructor." Drawing on appraisal theory, we are specifically interested in understanding how the design of collaborative online environments affect emotions in discussions and influence learner behavior.

A mixed-methods design was utilized to collect and analyze the online activities of 404 participants in 14 fully online graduate education courses hosted by a large, metropolitan university. The courses were offered on 'PeppeR,' a collaborative conferencing platform used across the University (Hewitt, 2009). The platform's features include threaded discussions, public and private notes, and replies, notifications, links, and other social media-inspired features such as the like button.

To detect the linguistic and emotional tone of a note, we used machine learning models built into IBM Watson's Tone Analyzer over more than 19,000 notes (IBM, 2019). To derive emotion scores from the text, IBM uses a stacked generalization-based ensemble framework; stacked generalization uses a high-level model to combine lower-level models to achieve greater predictive accuracy. Features such as n-grams (unigrams, bigrams, and trigrams), punctuation, emoticons, curse words, greetings, and sentiment polarity are fed into machine-learning algorithms to classify emotion categories. We then performed a chi-squared analysis of tones obtained in different courses for different students in various types of interactions. Given the extremely low p values ($p=2.55078E-46$), we conclude that the various types of interactions have a high impact on the emotional and linguistic tone of learners. The analysis uncovered significant differences in tone when the following comparisons were made: across different courses, across different users, public notes versus private notes, instructor notes compared to student notes, notes that begin a thread versus replies and notes that have been replied to compared to those that did not receive a reply. Collectively, this evidence suggests that carefully-designed affective interactions can have a positive impact on student learning in online courses.

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