WIP: Leveraging Learning Analytics to Explore Elementary Students Collaboration and Affect in Engineering Design Challenges

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***Abstract*—This research work-in-progress paper reports on a proof of concept trial of an augmented reality learning platform that aims to unobtrusively capture elementary students' collaborative actions and affective states. With the growing push to integrate engineering education in K-12 settings, elementary teachers and students face many implementation challenges. In particular, while engineering design projects can serve as a context for developing collaborative skills, younger students might find open-ended projects where working with others who have different views than their own especially difficult. Such projects may also force young students to contend with several emotions. In this space, we propose MindLabs, an augmented reality platform for engaging in integrated science and engineering design projects. In a pilot study 216 elementary students on teams completed a lesson on forces and motions which ended with a two-day design challenge. While students interacted with the system, their collaborative actions and use of the affective state reporting tool were captured. Using learning analytics and more specifically exploratory data visualization, we present three cases that demonstrate positive and negative collaboration dynamics and affect reporting differences. We discuss how the results relate to past research on collaboration dynamics, affect and conflict and how these analytics could support teachers to identify and assist different groups of students. We conclude with future steps for this project.**

Keywords—affect and emotion, engineering design, project-based learning, learning analytics

I. INTRODUCTION

In this research work-in-progress paper we present a preliminary analysis of how elementary students managed their collaborative and affective responses while solving an engineering design challenge about simple physics machines. There has been a growing push to integrate engineering education in K-12 education following the introduction of the Next Generation Science Standards in the United States [1]. At the elementary school level, teachers have noted several challenges including lack of resources, students' unfamiliarity with collaborative project work and other constraints [2], [3] In particular, elementary students may find collaborative work in open-ended design problems challenging as they navigate uncertainties in the task and different or conflicting views among their teammates. Engineering design projects have the potential to forefront the affective dimensions of learning, however, it is also possible that these students' affective responses to open-ended problems and teamwork adds more complexity to these learning environments. Historically, while there has been research on affect or emotions in learning [4], [5], [6] and on engineering design (e.g., [7]), there is limited research on how these two intersect, especially for younger students. In this nascent area, we introduce MindLabs (ML), an augmented reality platform that seeks to support students developing engineering design skills and affect recognition and regulation. ML features a robust data logging system that unobtrusively captures students' design actions, collaborative actions, and self-reported affective states as they work on a design challenge.

ML with its new data logging system was piloted in a midwestern school, where 216 elementary students worked on teams to complete a five-lesson project with a two-day design challenge where they were tasked to develop a system for transporting a ball using MindLabs software. To understand how students managed or struggled with collaborating and their affective responses, we ask: *In what* *ways did student teams exhibit different collaboration styles and affective reporting while completing the design task*?

For this study we draw on learning analytics, which typically involves the collection of learning process data from a digital environment and subsequent analysis, drawing on techniques from data science and related areas. More specifically we draw on exploratory data visualization [8], [9] to inductively explore any relationships between students' collaboration processes and affective responses over the course of their project. Any insights discovered on the relationship between students' collaborative actions and affect could be shared through reports or learning analytics dashboards in real time (e.g. [10]) to empower teachers to get a full picture of teams learning process and provide direction on which teams do or do not need support. In the next section we briefly review challenges and opportunities with teaching engineering design in elementary schools, collaborative learning, and emotions in education. Next, we review the methods of data collection and analysis as well as the context of the study. In the results we present 3 distinct cases that visualize students collaborative and affective actions before closing out with a discussion of findings and next steps.

II. Literature Review

A. Engineering Design in K-12

The passage of NGSS [1] and other initiatives have led to greater integration of engineering education, particularly engineering design projects, into K-12 schools. Challenges with integrating engineering in K-12 settings have been notably stark for K-5 elementary schools [11]. Elementary school teachers have highlighted many difficulties, including insufficient resources and lack of materials to assist with integrating engineering into their classrooms, students' lack of readiness for collaborative work, and constraints within the academic calendar [2], [3]. These teachers have also reported feeling underprepared to integrate engineering into their classrooms [11], [12]. Despite these difficulties, several have noted the team-based nature of engineering design challenges affords opportunities for developing collaborative abilities [13].

B. Collaborative Learning

There are different perspectives and implementation of collaborative learning or team-based learning. Depending on the intent behind the team-based instruction, there are three levels of collaborative learning: casual groups, cooperative learning, and team-based learning [14]. Casual groups are set up when the instructor pairs students spontaneously with the aim of completing a single classroom activity; cooperative learning involves sporadic group activities intentionally implemented in a course, whereas collaborative learning requires utilizing the strength of student teamwork as part of course structure. Teamwork in educational settings has implications such as improved academic performance; meaningful learning because of peer discussions; and developing professional skills such as project management, leadership, and communication [15], [16], [17], [18]. However, both students and instructors experience challenges in implementing teamwork due to lack of instructional experience in such settings, mismatched levels of commitment between team members, social loafing, and team dysfunction due to incoherence.

C. Emotions in Learning

Several researchers have studied the association of emotions with learning, ranging from populations of elementary to post-secondary students and even teachers as learners (e.g. [5]). Some authors consider science learning as a complex, emotional, and social process where practices lead to deeper understanding when integrated with feelings [4]. Affective or emotional in combination with cognitive and social dimensions affect a student's engagement with science learning tasks and in turn the construction of epistemic emotions [19]. Other scholars have studied the more specific emotions of curiosity and interest and found positive associations with science learning [20]. Furthermore, the integration of gamification and VR technology with learning has led to several studies that focus on emotions [21], [22]. Hawes and Arya [22] observed a decrease in anxiety and increase in cognitive performance in VR gamification contexts. Cheng and colleagues' [21] findings suggest that students experienced both positive and negative emotions in playing games and negative emotions were instrumental for long term retention of knowledge.

III. Methods and Study Context

A. Learning Analytics and Exploratory Data Visualization

Learning analytics as a research method involves generating metrics to assess or understand students' learning processes and outcomes through data traces collected in digital platforms such as simulations, learning management systems, or other digital environments. Exploratory data visualization is one learning analytics technique that relies on data visualization approaches to identify meaningful patterns and insights from students' learning process data [8]. Data visualizations are powerful because they can flexibly display multidimensional data [23], enable comparisons across different variables [24], and support rich cross-case comparisons of visualized entities (e.g., see [25]). This technique is exploratory both in that it is used to develop an initial understanding of newer data sources and that it is used before more formal models or representations of the data have been developed. These visualizations can lead to insights about key features or variation in students' learning processes, supporting the development of more nuanced models that better account for student learning in all its forms.

B. Study Context and Participants

The study took place in nine fourth-grade classrooms in a suburban school in the Midwest. Before beginning the force and motion lessons, the students had little engineering design experience. The force and motion lessons covered the NGSS physical science core ideas relating to energy and energy transfer. Additionally, the lessons included engineering practices focused on problem-solving through design solutions. There were 216 total students, working in groups of three to four students for a total of 68 teams. The activity

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involved five 60-minute lessons to investigate force and motion using AR culminating in a design challenge where they were asked to develop a course to move a ball using simple machines. The design challenge happened on the last two days of the unit.

C. Platform and Data Collection

The platform students used for this activity is called Mindlabs. MindLabs consists of a mobile application and web-based platform that utilizes augmented reality to facilitate hands-on problem-solving and creative design to learn principles of science and engineering collaboratively. Increasingly many digital learning environments unobtrusively log student actions or events in the platform [26], [27]. These can be used both to study students learning processes and may be leveraged to provide feedback to students based on their actions within the system. Mindlabs likewise employs unobtrusive logging; as students use the platform, their activities are logged on their individual device, and teams can work in a shared workspace. There are four logging streams including 1) a time sequence of design or collaborative actions 2) student-to-student feedback to teammates, 3) student self-reported emotions or affective state, and 4) reflections or entries into their engineering journal. For the present work we focus on students' design or collaborative actions and affective reporting to understand the relationship between these two data streams. Design actions include what part was manipulated (e.g., a spring or an incline), a time stamp, the ID of the student taking the action, and whether it was an add, remove or edit action. Affective data included an affective state, timestamp, and student ID to document who reported it. Affective states could be selected from sixteen states grouped into four categories (e.g., happy, sad, worried, and frustrated feelings) via a sidebar panel in the platform. Teachers encouraged students to use the affect self-reporting panel.

D. Data Analysis

In this work we draw on past data visualizations approaches [25] to create visualizations that juxtapose students' design actions with their affective reporting. The plots reflect team design or collaborative actions and affective reporting during the design challenge segment of the project. Design actions are color-coded for the team member who enacted it, as are affective reports. Following qualitative and mixed methods researchers [28] we sought to identify distinct cases or variability in how students collaborated and shared affective states. This resulted in three distinct cases presented below. The plots are split into class sessions (e.g., S1 is session 1) and the width of these panels is based on when students were actively using the platform.

IV. Results

In these preliminary results we first present a high-level overview of students' engagement with Mindlabs and specifically their collaborative actions and affective reporting. Following this, we present three different team-level visualizations or cases that show distinct ways teams collaborated and shared their affective states. While all teams used Mindlabs to design a simple machine system and share their affective states, use of both of these features varied widely. Note for these results, we focus on teams that had at least two members that were active for part of the project to avoid reporting on teams that had school absences or technical glitches with how data was captured. Over all the teams that had two or more partially active members, affective reporting over the two-day period of the design project spanned 6 to 40 affective reports. Collaborative actions, on the other hand, spanned 20 to 238 actions. Thus, the spread for both of these features is large.

A. Case 1: Team with Positive Affect and Shared Collaboration

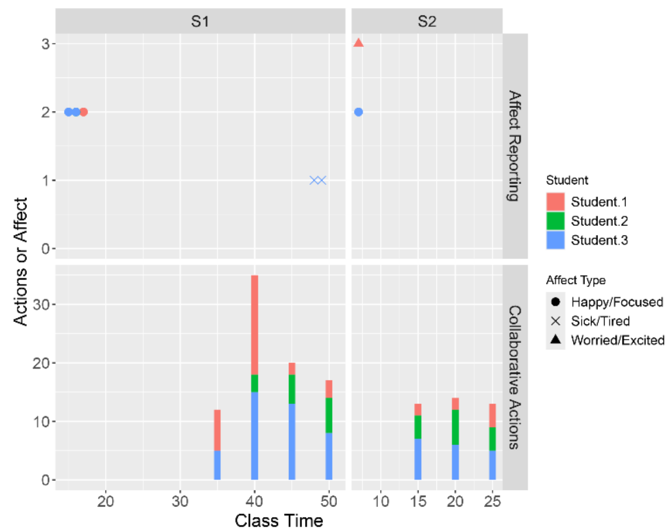

Figure 1 Team 67

Team 67 began the project with two of its three members reporting feeling happy and focused. As they started to work on the project, each of the three members contributed to working on the system. Toward the end of the first day, one member who had been fairly active reported being sick or tired. Starting on the second day, that same member reported feeling happy and focused, while another reported being worried or excited. Although there was more variation in reporting at the beginning of the second day, each member contributed the overall system design, although their number of actions was lower than the day before.

B. Case 2: Team with Negative Affect and Disengaged Member

Team 52 began the project with some reporting of being happy and focused, although one of the members shifted between reports of being mad and happy multiple times. On S1, Student 1, who had reported these mixed feelings, participates in the project some, however, Student 2 is far more active than them. Student 3 also shows little activity. On the next day, Students 2 and 3 report feeling happy. Student 1, however, reports feeling worried and does not participate in the design at all. Activities are dominated by Student 2, with some activity from Student 3, unlike the day before. Student 3 shifts from reporting being happy, to worried, to mad, throughout this process while Student 1 remains disengaged, suggesting the team may be struggling.

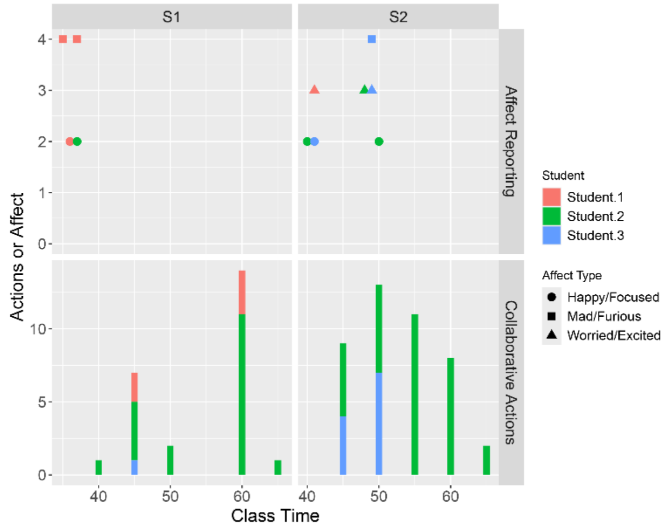

Figure 2 Team 52

C. Team with Low Engagement and Variable Affect Reporting

This team begins with several reports of being sick or tired, although Student 3 reports feeling happy. Activity during S1 is low with only a few actions and a large stretch of no designing. Toward the end, Students 2 and 3 report feeling happy again, although student 3 reports feeling sick or tired again not long after. On the second day, overall activities remain low, with only student 2 contributing anything. At the same time, students report many different affective states in rapid succession. The low collaboration activity and rapid shifting of affective reporting seems to suggest the team is not on task or that their motivation is low or variable.

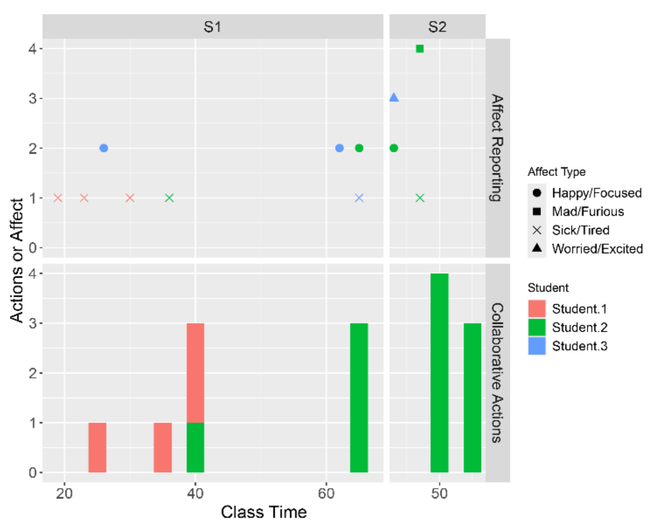

Figure 3 Team 59

V. Discussion and Future Steps

The preliminary analysis of elementary students design teams collaborative interactions and affective reporting have a few key takeaways. First and foremost, the collaborative patterns expressed by the different teams reflect team dynamics found in past research. Team 67 resembles a well-functioning team where each member contributes relatively evenly. While they express some positive and later negative affect states, the team in general reports feeling happy or focused in most of their instances. Team 52 on the other hand reflect patterns of team conflict [29] or possibly a dominating team member (e.g., [30]). The high level of activity from Student 2, and negative affect from Student 1, leading to their non-participation suggest some conflict is happening between these team members. Past research on team conflict has identified a variety of types of conflict, from conflict over the nature of the task, to relational conflict between team members to process conflicts over how to complete the task [29]. While the log does not provide enough information to indicate which type of conflict this may be, it does provide enough information for a teacher to check-in on the team and probe into what may be happening. Finally, in the case of team 59, most team members show few collaborative actions. This relates to work on social loafing in teams, where one or more team members do not participate in the team process [31]. Notably here, most of the team appears to be inactive, suggesting a team level of social loafing and members who do not feel accountable to each other or the task. Other contextual factors may be operating, but this low level of activity may be an indicator for the teacher that a check-in is needed.

Turning more specifically to affect, Team 67 and 52's affect reporting seems to show a clear relationship with their collaboration levels and participation. However, the wide spread of affective reporting in Team 59 shows a less clear relationship to their collaboration levels. This may require deeper probing from the teacher to understand, but still provides some feedback for understanding where teams are at. The goal of the ML system is to help students reflect on their own emotions while collaborating, to support them in developing emotional regulation skills [6]. Additionally, this reporting could be shared through a teacher dashboard (e.g., [10]) which should assist the teacher to identify when they need to intervene when conflicts or team dynamics become disruptive or harmful.

Past research in science education has uncovered that emotions can vary widely during science projects, from excitement, to frustration to disappointment and relief (e.g., see [4], [5]). We see similar affect patterns while elementary student teams work on their design projects. For instance, although team 67 started with several members reporting feeling happy and focused, members of the team later reported feeling tired and worried as the project progressed, suggesting the interaction between design work, students, and their teammates is complex and dynamic. Past work in science education has also identified that students who are passive or inactive in project-based learning may exhibit a range of emotions, which may be related to their lower activity in the project [19]. This may partially explain what is happening with team 59, although more research is needed to examine this. In future work we plan to extend this analysis by identifying both similar cases of team collaboration and affective reporting as well as new patterns not yet observed. From this we will have a more comprehensive list of the ways elementary students collaborate and report their emotions, which we will analyze to extract key (quantitative) features that distinguish what patterns a team appears to be expressing. Additionally, we will collect new rounds of data which will include more teacher interviews and student interviews to help provide greater validation or needed revisions to patterns identified here. The long-term vision of this work is to build these insights back into a teacher dashboard to help them understand and better support students throughout the project.

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