WIP: The First-Year Engineer's Learning Journey

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Abstract

In this Work-in-Progress paper, our goal is to share the tools, approaches, and analysis methods and how that might inform our understanding of the student's journey through their first engineering course. To gain insight into students' learning and emotions, we introduced a reflection assignment in the first-semester engineering course during Fall 2021. This reflection had students map their learning and emotions during the course. We adapted the quantitative approach of the Emotion Learning Model (ELM) and the qualitative approach of the Mental Model Matrix (MMM) to analyze these learning journey maps. From this analysis, we were able to identify the negative and positive effects and negative and positive learning that occurred in one of the units in our first semester engineering class at Michigan Technological University.

Introduction

The first year of a student's college experience is one of significant learning and transition. For many, it represents the first time they are living away from home, navigating adult responsibilities and decisions, and forging new friendships and support systems. This transition is particularly pronounced for engineering students, who not only contend with these common challenges but also face the demands of a rigorous academic curriculum. At Michigan Technological University, the first year for engineering students is characterized by a common two-course sequence designed to lay a solid foundation for their academic and professional journey. These courses are carefully crafted to address key skills and competencies vital for success in the field of engineering. They cover a spectrum of topics including communication, ethics, problem-solving, spatial visualization, programming, and 3D modeling.

For example, one notable aspect of the first-year engineering sequence is the introduction to programming, specifically with MATLAB, a widely used software platform in engineering disciplines. While programming skills are increasingly essential in today's technological landscape, many first-year students may encounter MATLAB for the first time during these courses. This can potentially add to the stress and challenges already inherent in the transition to college life.

To support students through this learning curve, Michigan Tech provides various resources and support systems. This might include dedicated tutoring or mentoring programs, workshops or seminars on programming fundamentals, and accessible faculty or teaching assistants for guidance and clarification. Additionally, fostering a collaborative learning environment where students can seek help from peers has been invaluable in easing the transition into MATLAB programming and other aspects of the curriculum.

After attending a d.school Teaching and Learning Studio and being asked to document their own learning journey through an activity [1], two of the co-authors wanted to help students in the first-year engineering courses reflect on both their learning and emotional journeys throughout their first course. In particular, we wanted to focus our study on this study of MATLAB and

identify where students struggled in the learning of the material and where they struggled emotionally in the content.

Student Learning Journey Mapping

One definition of a journey map is a visual representation of a person's journey throughout an experience. Figure 1 below shows the version developed by the d.school and explains how the learning journey process works [2]. In our program, our first-semester engineering course consisted of four units: Ethics & Communication, Problem Solving, Programs & Functions, Data Representation & Analysis, and Conditionals & Loops. We had students create a learning journey map for Units 2-4 as students were beyond the first few weeks of the semester and these represented more technical content. For each of these units, a short description of the lessons for that segment of the course were provided for the students and students were instructed to draw their learning throughout the unit (red line) and emotions (blue line) and add a description using text boxes or Post-it notes to provide context for their journey. Example student learning journeys for Units 2-4 are shown in Figures 2-4.

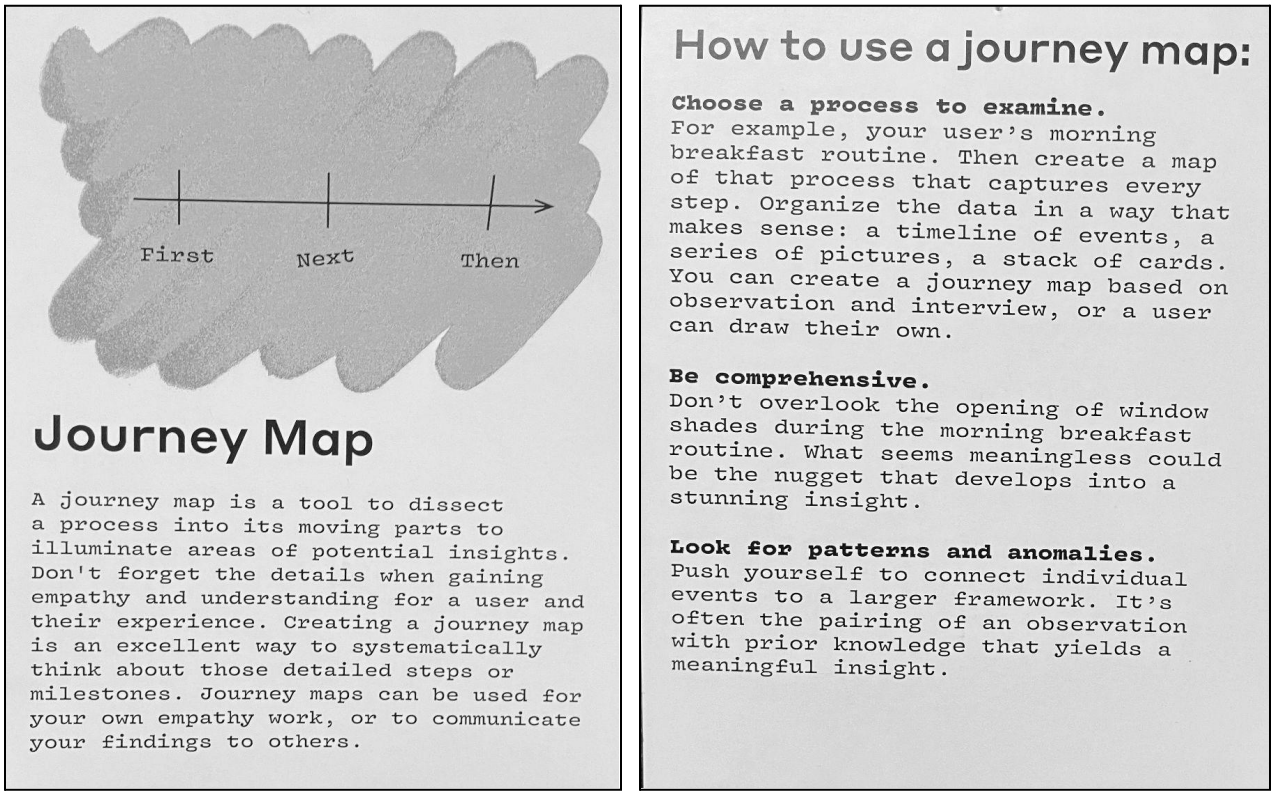


Figure 1. d.school Design Thinking Bootleg Card: Journey Map [2]

In Unit 2, students were introduced to a problem-solving methodology (SOLVEM), unit conversions, MS Excel, and topics around programming in MATLAB. In Unit 3, students continued to expand their knowledge of Excel and MATLAB and focused on representing data in graphs. In Unit 4, students were introduced to conditional statements and loops and had three application problems that spanned five of the days of this unit. One student provided the

following comment along with their submission, “I really enjoyed these Journey Maps and they're a simple and effective way of learning how to learn, and how stress affects learning and vice versa. Continue with these please!! I plan on making my own for future classes.”

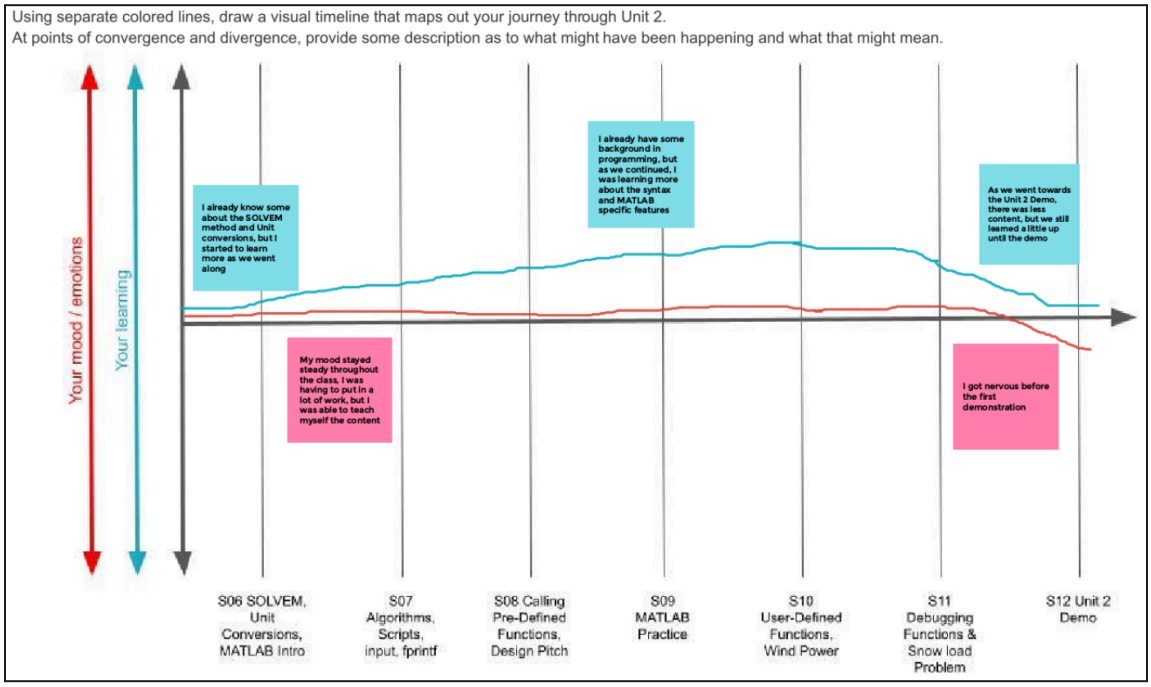


Figure 2. Example ENG1101 Student Learning and Emotional Journey through Unit 2

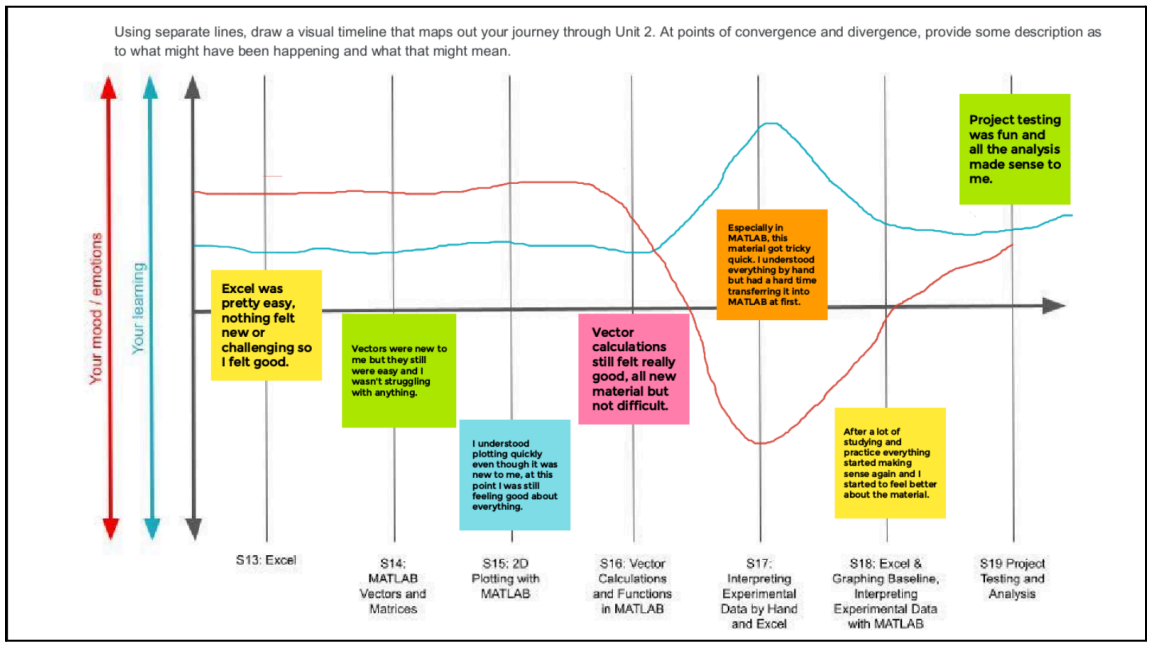


Figure 3. Example ENG1101 Student Learning and Emotional Journey through Unit 3

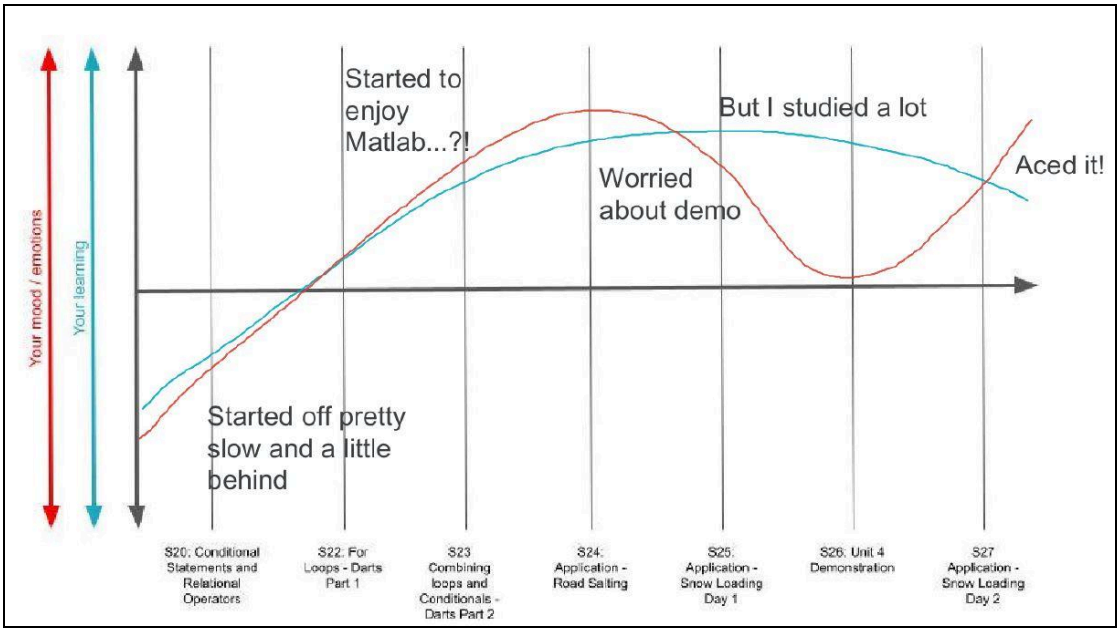


Figure 4. Example ENG1101 Student Learning and Emotional Journey through Unit 4

There is a lot of data to unpack in these learning journeys, but our analysis in this WIP paper will primarily focus on the Unit 2 learning journeys. When we started this unit in Fall 2021, one instructor noticed that after session 8 (S08), the students appeared to be overwhelmed and a practice day (S09) was added to the unit. This journey map reflection was implemented after the students completed the exam (Unit 2 demo) to see how the students responded to this change in order to inform future adjustments to the first-year curriculum. Our methods for analysis and results are discussed in the following sections.

Methods

We employed a dual-method approach, combining quantitative and qualitative analyses to examine student emotions and learning experiences during the unit. Our methodology involved the adaptation of the quantitative approach of the Emotion Learning Model (ELM) [3] and the qualitative approach of the Mental Model Matrix (MMM) [4].

Quantitative Analysis using ELM:

The ELM served as a framework to transform students' emotional and learning experiences into the ELM quadrants. Students actively engaged in mapping positive and negative emotion lines alongside positive and negative learning lines, creating a visual representation of their journey throughout the unit. The categorization into ELM quadrants involved precise counting for further quantitative analysis:

- Quadrant I (Positive affect & learning): Indicates a scenario where students experience positive emotions alongside effective learning.
- Quadrant II (Negative affect & positive learning): Signifies instances where students encounter negative emotions but still exhibit positive learning outcomes.

- Quadrant III (Negative affect and un-learning): Highlights situations where negative emotions are coupled with a decline in learning effectiveness.
- Quadrant IV (Positive affect & negative learning): Represents scenarios where students experience positive emotions but exhibit a decline in learning effectiveness.

Qualitative Analysis using MMM:

Conducting a qualitative analysis alongside the quantitative approach of ELM,, we employed the four-dimensional Mental Model Matrix (MMM) [4] to gain deeper insights into students' emotions and learning. A mental model is a conceptual framework that elucidates thought processes and aids individuals in navigating the world. As defined by Borders, Klein & Besuijen (2019), MMM encompasses four components: Positive aspects of how the system/class works, Negative aspects of how the system/class fails, Positive strategies to make the system/class work positively, and Negative aspects of how learners get confused [5]. This tool facilitated a qualitative evaluation of learners' self-reflection and self-explanation.

The steps involved in the MMM analysis encompassed: 1) aggregating all student comment results from their journey maps into a single matrix with four quadrants; 2) eliminating overlapping and redundant student comments; 3) reviewing the refined metrics and selecting pertinent comments; and 4) analyzing the synthesized metrics to provide a couple of illustrative examples for each dimension.

ELM Results and Findings

In our examination of emotions and learning around Session 09 (S09), we employed the Emotion Learning Model (ELM) quantitatively. By categorizing students into four quadrants, we derived percentages for each quadrant, providing nuanced insights into their experiences. Approximately 55% fell into Quadrant I (positive affect & learning), with an additional 27% in Quadrant II (negative affect & positive learning). Meanwhile, 15% were in Quadrant III (negative affect and un-learning) and 3% were in Quadrant IV (positive affect and un-learning). Diverse student comments that exemplify their coding/MATLAB experience are demonstrated in Figure 5b.

Moreover, exploration into the student comments within the ELM quadrants revealed:

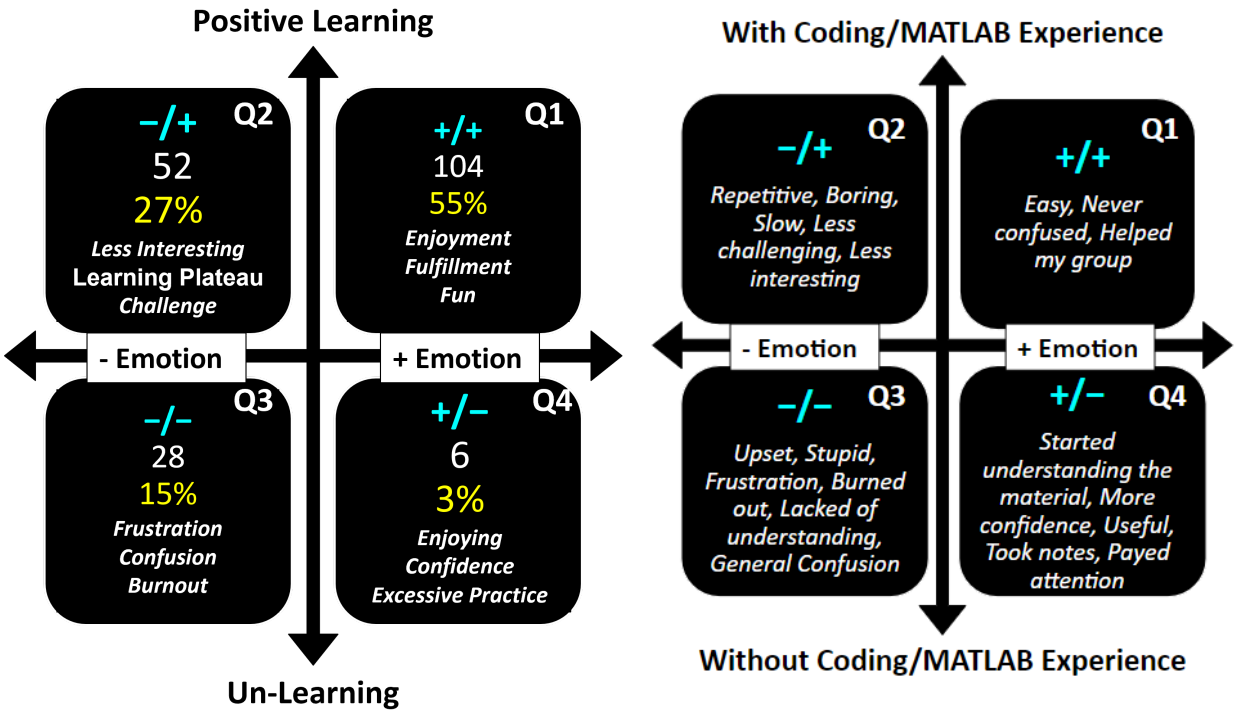
Quadrant I (Positive affect & learning):

The positive emotions expressed in this quadrant align with a sense of enjoyment and fulfillment derived from learning MATLAB. As one student notes, "Saw what could be done using MATLAB, and it started to get fun creating new scripts and functions to solve problems." Another student highlights the effectiveness of practice sessions, stating, "The practice session helped greatly, and I feel I understand the concepts we are learning in class." These comments indicate that positive emotions contribute to an engaging learning experience.

Quadrant II (Negative affect & positive learning):

Students in this quadrant express a diminishing interest and challenge in the learning process, even though they acknowledge positive outcomes from specific learning elements. A student

remarks, "I still liked spending time on MATLAB here, but it started to become less challenging and therefore less interesting." Another student reflects on a learning plateau, saying, "Once I learned functions, the learning plateaued." These comments suggest a need for varied and engaging activities to maintain motivation and interest throughout the unit.



(a) *(b)*

Figure 5. EML Results for ENG1101 Students during S09

Quadrant III (Negative affect and un-learning):

The comments in this quadrant highlight a decline in both mood and learning effectiveness over time. A student expresses frustration and confusion, stating, "My mood and learning started to drop off as we kept going on with the same thing for a long time." Another student points out the onset of burnout, noting, "Burnout started to set in, and frustration built up to the point where I felt that my brain could not process information anymore." These experiences underscore the importance of recognizing signs of distress and implementing strategies to prevent prolonged negative affect and learning regression.

Quadrant IV (Positive affect & negative learning):

Students in this quadrant exhibit positive emotions while acknowledging limitations in their learning experiences. For instance, a student shares, "During MATLAB practice, I did not learn anything, but I like MATLAB, so I was enjoying class." This sentiment reflects a positive emotional connection to the subject matter despite a perceived lack of substantial learning during practice sessions. Furthermore, an individual expresses a keen interest in programming but voices dissatisfaction with excessive practice, stating, "I enjoy programming, so I've been

enjoying the work for this class, but the large amount of practice was unnecessary." These comments underscore the importance of striking a balance between fostering positive affect and ensuring optimal learning outcomes. The acknowledgment of positive emotions alongside challenges in learning highlights the complex interplay within this quadrant.

In conclusion, understanding the intricate relationship between emotions and learning is crucial for creating a conducive educational environment. The ELM framework proves valuable in identifying these patterns and guiding educators towards a more nuanced understanding of student experiences.

MMM Results and Findings

Our qualitative analysis, employing the adapted Mental Model Matrix (MMM), provided a holistic evaluation of student comments across four dimensions: system/class operation (positive and negative), and personal/emotional aspects (positive and negative).

System/Class Operation - How the System/Class Works (Positive +):

Students expressed positive sentiments regarding how the system/class works, emphasizing their enjoyment of learning MATLAB syntax and its practical applications through creating scripts and functions.

System/Class Operation - How the System/Class Fails (Negative -):

Negative aspects in system/class operation were identified, with concerns raised about the perceived redundancy of a large amount of practice. Some students found the tasks less challenging and, consequently, less interesting.

Person/Emotion - How to Make the System/Class Works (Positive +):

Positive reflections on personal emotions indicated an increasing familiarity with the content and growing comfort. Taking notes and paying attention during the learning process contributed to improved mood and comfort.

Person/Emotion - How Learners Get Confused (Negative -):

Negative emotional responses were associated with initial difficulties, confusion, and frustration due to a lack of understanding, particularly for students with no prior coding experience. Some felt upset when facing challenges in learning MATLAB.

This four-dimensional analysis provides a nuanced understanding of students' perceptions, offering insights into both positive and negative aspects of system/class operation and personal emotions during the MATLAB learning experience. Further details, including specific student comments, are presented in Table 1 below.

Table 1. MMM Preliminary Emergent Themes from Student Comments around S09

	Positive (+)	Negative (-)
System / Class	**How the system/class works:** Parts, connections, logics, causal relationships ● I learned the syntax and was just practicing applying it in different examples. ● Saw what could be done using MATLAB and it started to get fun creating new scripts and functions to solve problems.	**How the system/class fails:** Breakdowns and limitations ● The large amount of practice was unnecessary. ● I still liked spending time on MATLAB here, but it started to become less challenging and therefore less interesting.
Person/ Emotion	**How to make the system/class works:** Detecting anomalies, appreciating the system's responsiveness, performing workarounds and adaptations.What have you learned? ● The content became more familiar and I became happier and more comfortable. ● When we first started to learn MATLAB things got rough for a bit until I started to really pay attention and take notes on the ESP and then things have been up since then.	**How users get confused:** The kinds of errors people are likely to make. What would you like to learn more? ● My mood dropped pretty negatively in the first half due to lack of understanding and general confusion. I have no experience in coding so it was really difficult at first, however once I got a better understanding of syntax I felt a lot better. ● Was very upset because I was not learning MATLAB well, and I felt stupid.

Discussion

The initial analysis points to some interesting results and indicates the need to dig deeper into the analysis with respect to prior programming experience. While the initial goal of implementing learning journeys was to look at the effects of a specific intervention (e.g., adding S09) on students' learning and emotions, this proved to be an opportunity to help instructors better understand the individual contexts in which students are trying to learn throughout the entire semester. In the analysis of the Unit 2 learning journeys, the results indicated that while the majority of students were seeing positive affect and learning, there is a need to recognize the signs of distress which may indicate negative affect and unlearning of course materials. Additionally, approximately a quarter of the students indicated the need for varied and engaging activities to maintain motivation and interest throughout the unit.

The next step of this study will be to analyze the learning journey reflections that were added after each course unit to get a sense of the learning and emotions of the students throughout the entire first-semester course at Michigan Tech. This will help us identify areas of positive affect and learning and where additional learning strategies should be implemented to increase student and course outcomes.

References

[1] D.H.N. Ayutthaya and P. Koomsap. Student Learning Journey Map: A Design Toolkit for Enriching Learning Experience, 2022.

[2] d.School “Design Thinking Bootleg” https://dschool.stanford.edu/resources/design-thinking-bootleg. Web Accessed 3/24/24.
[3] B. Kort, R. Reilly, and R.W. Picard. “An affective model of interplay between emotions and learning: Reengineering educational pedagogy-building a learning companion.” In Proceedings IEEE international conference on advanced learning technologies. pp. 43-46, August 2001.
[4] J. Borders, G. Klein and R. Besuijen. “An operational account of mental models: A pilot study.” In the International Conference on Naturalistic Decision Making. 2019
[5] Y-Y. Tan and S-L. Yang. “Assessing student calculus learning using the Mental Model Matrix.” Poster presented at the AAC&U Conference on General Education, Pedagogy, and Assessment From Reflection to Imagination: Making Excellence the “NEW Normal”, San Diego. 2022.