Exploring Factors Impacting Students' Engagement in a College Precalculus Course

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This study aimed to gain insight into students' experiences of engagement in undergraduate Precalculus. A series of interviews were conducted with a group of 12 college students to solicit their lived experiences of engagement, using methods of hermeneutic phenomenology. The analysis uncovers that some of the key factors influencing engagement include the physical layout of the classroom, the nature of student-instructor and student-peer relationships, students' comfort level with the course material, and their interpretation of grades as formative feedback. Insights gained from these findings can provide us with important information about how students engage in college Precalculus and suggest ways to improve the teaching of the course.

Keywords: engagement, precalculus, student experiences, phenomenology.

Researchers and educators would agree that engagement is an integral part of the learning process, so engaging students in mathematics is viewed as an important goal at both the undergraduate and K-12 levels of education (Middleton et al., 2017). Efforts aiming to increase college students' success in mathematics courses emphasize the importance of student-centered instruction, providing supports for learners, and implementing pedagogies that promote students' active participation in the learning process (e.g., Apkarian et al., 2021; Rasmussen et al., 2019).

As we push for certain curricula and instructional approaches, it is important to consider not just the dehumanized numbers quantifying success and failure, but also the lived experiences of students who are on the receiving end of these reforms. Some questions we ought to consider include: Would students themselves say that they feel engaged in these classrooms? What does engagement look like for them? The study presented here aim to promote this conversation and shed light on factors that students experience as impactful on their engagement. The data and findings are part of a larger phenomenological study on students' experiences of engagement in college Precalculus.

Literature Review and Theoretical Framework

Precalculus is one of the more common gatekeepers to entering STEM majors in universities and colleges, while also ironically playing the role of a terminal mathematic course for certain majors in some universities (Bailey et al., 2008; Ganga & Mazzariello, 2018; Roksa et al., 2009; Seymour & Hewitt, 1997; Seymour & Hunter, 2019). In the last 14 years, groups of researchers in the US RUME community have conducted a number of large-scale national studies of the college-level Precalculus-Calculus sequence (Apkarian & Kirin, 2017; Bressoud et al., 2015; Rasmussen et al., 2019). The findings from these studies produced a plethora of insights into multiple aspects of teaching and learning in these mathematics courses. However, there is still a growing need for research on affective aspects (which includes engagement) of college-level mathematics instruction (Melhuish et al., 2022), and a need for more research that solicits students' perspectives on their own learning (e.g., Leyva et al., 2021).

Mathematics Engagement

Despite its importance, there is no consensus on the conceptualization of student engagement in broader education research (e.g., Appleton et al., 2008; Wong & Liem, 2022). A commonly adopted framing in K-12 mathematics education comes from Fredricks et al. (2004) that positions engagement as a dynamic, malleable, multi-dimensional meta-construct (Middleton et al., 2017). In their Compendium chapter Middleton et al. (2017) note the complexity of the phenomenon, which makes engagement rather difficult to research, especially when it happens in the moment.

When it comes to the multiple dimensions of engagement, the three most common ones are: affect, behavior, and cognition. Affective or emotional engagement is oriented towards students' emotional reactions to aspects of schooling (e.g., interest, feeling of belonging, attitudes, relationships, etc.). Behavioral engagement is oriented towards participation in schooling (e.g., positive conduct, effort and involvement in learning, participation in school-related activities, etc.). Cognitive engagement, which is oriented towards students' investment of effort in learning (e.g., investment in learning, self-regulation, setting and working towards learning goals, etc.). When considering students in the mathematics classroom, it is easier for instructors and researchers to observe behavioral engagement and much harder to glean students' affective and cognitive engagement.

Hermeneutic Phenomenology

The method used in the proposed study is hermeneutic phenomenology, which focuses on the human experience of a phenomenon, as well as the meaning of that experience (Friesen et al., 2012). The process of interpreting meaning is valuable in education research as it allows for contextualizing both the participants' experiences within the broader socio-cultural environment where learning happens, and the individual learner's personal disposition and interaction with education. This study builds on the interpretive approach of van Manen (2014) with the influence of the reflective lifeworld approach of Dahlberg, Drew, and Nystrom (2008).

Since student engagement is a complex and dynamic phenomenon, it makes sense that by exploring students' rich descriptions of their lived experience, we can get to the dynamic essence of engagement, as opposed to capturing a static image at some point in time. In order to conduct a phenomenological study, the methods of data collection need to emphasize soliciting students' descriptions of lived experiences of the phenomenon as they happened (van Manen, 2014).

Methods

This qualitative study was conducted at a large public university in the southeast United States during the Spring semester of 2024. Data collection involved a series of four audio- and video-recorded interviews with each participant that were spread out over the course of the semester. I also conducted non-recorded classroom observations of the sections attended by the participants with field notes. To support the interview process, the participants were asked to produce engagement artifacts and an engagement graph, which allowed them to respond to the interview questions in a more nuanced way producing rich qualitative data (Alibek, 2024).

Engagement Artifact

When asking participants to describe their experiences of engagement, interpreting data can be difficult since each participant have their own interpretation of engagement. Thus, it was critical to prompt the participants to explicate their conceptualization of the phenomenon. However, due to the complexity of the term, it would have been unfair to ask participants to produce a definition on the spot. Instead during each interview they were prompted to reflect and expand on ways they believe a college student can engage in their Precalculus course with additional prompts during each subsequent interview.

During Interview 1 participants were asked to jot down on paper their response to the following prompt: What are some ways you think a college student can be engaged in their Precalculus class? The produced artifact was brought back for Interview 2 for the participants to review and edit if they wished to do so. Additionally, during the second meeting they were asked to note the specific ways they have engaged in their Precalculus course themselves within the last week. Since engagement can manifest in similar ways across different disciplines, while simultaneously being discipline-specific, it was important to contrast the participants' experiences of engagement in Precalculus with their experiences in a different university course. This was brought in during Interview 3, when participants were asked to produce an engagement artifact for another class that they are enrolled in during that semester and then to compare it to the Precalculus engagement artifact. Finally, during Interview 4 participants were asked to do a final review and edit of their engagement artifact, as well as select one item that they felt was most representative of their engagement in the Precalculus course.

Graphing Mathematics Engagement

In addition to the engagement artifact the participants were asked to sketch how their self-reported engagement has shifted throughout the semester. Graphing as an elicitation tool is not a novel approach in neither education research more broadly (Bravington, 2023) nor mathematics education (Olarte, in press; Riske et al., 2021; Satyam et al., 2022). In fact, graphing is especially useful when dealing with constructs like engagement that involve affect, are malleable, and can significantly shift and change over time.

Participants were given a blank first quadrant of the coordinate plane and during each interview participants graphed their engagement up until the moment of the interview: first few weeks during the first interview, the weeks between the first and second interview during our second meeting, etc. Thus, each graphed segment covered around 3-4 weeks of the semester. Moreover, the graphs were all done on the same sheet of paper, so participants could review their sketches from previous interviews and build on them. Participants were provided alternative color markers to show how they would revise previously sketched graphs or letting them sketch the new segment in a different color if they desired to do so (e.g., Fig. 1 and 2).

It is important to reiterate here that the graphs were not analyzed by themselves: their main purpose was to elicit rich qualitative data and thick lived experience descriptions. Participants' graphs were not compared to each other as part of the data analysis. Instead graphs together with artifacts informed the interpretation of interview transcripts.

Participants and Context

At the beginning of the semester 12 participants enrolled in the research study, with only 9 participants completing all four interviews. The other 3 participants withdrew from the course at various points in the semester and thus couldn't complete all planned interviews. The data set includes a total of 42 participant interviews.

10 out of 12 participants in the study were enrolled in the flipped classroom sections, while the other 2 were enrolled in lecture-based sections. The flipped classroom sections of Precalculus at this university were coordinated for the most part. All students had to watch a set of videos, as well as solve and submit a short assignment prior to class. Once they were in the classroom, they worked in small groups to solve the worksheet problems from a printed packet, which they bought from the university. The in-class worksheets were never turned in for grades or feedback. Additionally, students had online ALEKS homework, weekly graded quizzes, three tests taken

during class time (corresponding to the three main content units of the course), as well as a cumulative final exam at the end of the semester.

While the overall findings are based on data from all 12 participants, the comparative examples used in this proposal focus on two participants from the study: Ashley and Beth, who despite having many similarities, had vastly different experiences with engagement. They were both freshmen at the university, who have taken a year-long Precalculus course during their junior year in high school. They were both enrolled in a flipped classroom section of Precalculus, taught by different instructors. Neither participant saw herself as a math person, but both were motivated and hard-working students, who aspired to get the best grade possible. However, while Ashley ended the semester feeling positive about her involvement in the course, Beth, on the other hand, voiced strong negative sentiments towards both the course and her engagement in it.

Data Analysis

This proposal focuses on the results of an intermediate analysis question within a larger study on student experiences of mathematics engagement in college Precalculus. The research question addressed in this presentation is: *What are some factors impacting students' engagement in college Precalculus?* The process of data analysis involved rounds of phenomenological bridling (Dahlberg et al., 2008), followed by reviewing participant interviews for lived experience descriptions of engagement (van Manen, 2014), and then writings narratives of experiences. The lived experience notes, phenomenological narratives, and interview transcripts were then analyzed across participants.

As a result of the analysis, certain factors consistently appeared across narratives of engagement experiences. Two participants, Ashley and Beth, were chosen to frame the findings due to their contrasting depictions of similar factors, informed by versus coding exercises (Palacios-Díaz & Moreno-Londoño, 2023). It's noteworthy that these factors resulted from a holistic analysis of the entire data set, not just Ashley and Beth's interviews.

Findings

When contrasting Ashley and Beth's experiences in the course, on the surface it seems like their stories of engagement couldn't be more different from each other. Ashley sustained a relatively high level of engagement throughout the semester and felt overall good about the course and her own learning at the end (Fig. 1). Beth on the other hand shared many frustrations about the course and how it is taught, she would regularly say that she doesn't really feel engaged in the class (which was reflected in her graph), and by the end of the semester she admitted that she can't wait for it to be over (Fig. 2). Despite these surface differences, data analysis has shown that there are certain aspects of the Precalculus course, instruction, and classroom environment that students see as impactful for their engagement and learning.

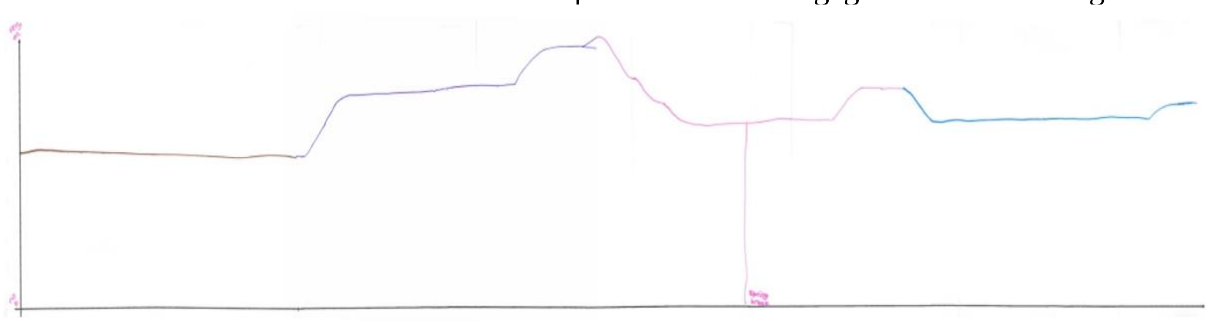

Figure 1. Ashley's final engagement graph.

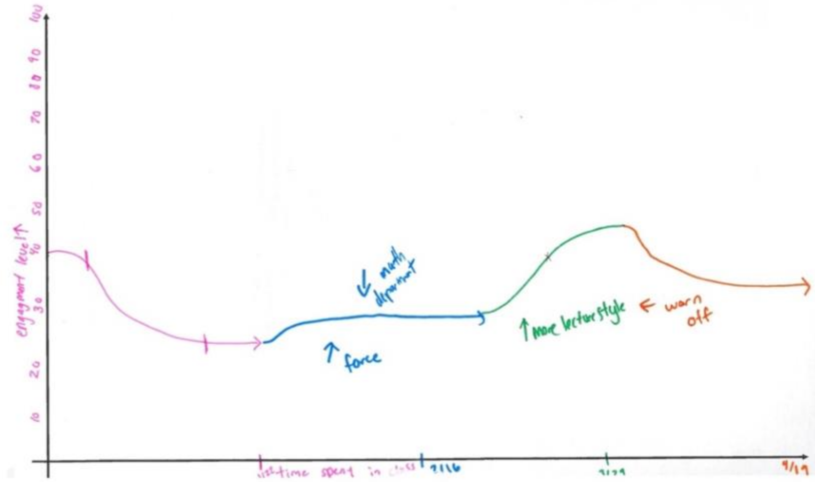

Figure 2. Beth's final engagement graph.

Physical Layout of the Classroom

Participants brought up the physical setup of their classrooms when discussing engagement, especially the way tables are set up for groupwork. When working on her engagement artifact, Beth said that one of the ways students can engage in a Precalculus course is by sitting at round tables, or at least facing each other (Fig. 3, left). However, she later noted that this is something she experienced in her high school Precalculus class, but not in her college course. Beth noted that her college Precalculus classroom had tables that were set up for a lecture-style class, where she had to move to work in a group with other students (Fig. 3, right).

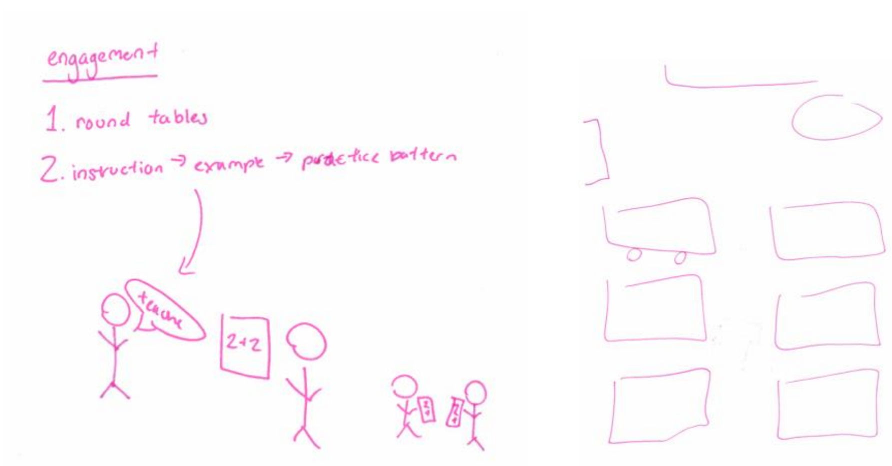

Figure 3. Beth's first engagement artifact (left) and sketch of her classroom (right).

Ashley also noted that sitting together with other people and facing each other helps her feel engaged during class. She contrasted it with her experience in another lecture-based Precalculus section that she attended once during the add/drop week. She said that sitting at her desk, not looking at other people caused her to feel disengaged, which was one of the reasons she switched sections. Similarly to Beth, in her artifact Ashley noted the physical classroom setup as one of the ways to engage (Fig. 4, right) compared to the disengaging lecture setup on the left (Fig. 4).

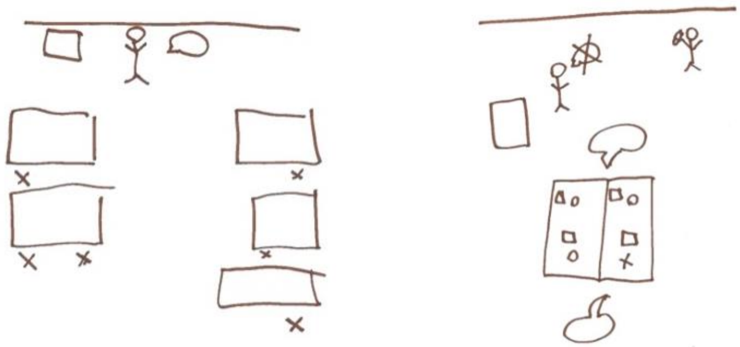

Figure 4. Ashley's first engagement artifact for the lecture class (left) and flipped class (right).

Relationality of engagement

When it comes to learning environments, it's not just the physical setup of the class that impacted participants' engagement. The students in this study noted the great role that the relationships play in the way they experience engagement.

First, classmate relationships greatly influence engagement, particularly in a flipped classroom. Initially, Ashley felt less competent in mathematics than her peers, leading to self-consciousness. However, she grew comfortable with her group and with asking questions during class, attributing her active engagement to the supportive learning environment. Conversely, Beth felt her group members knew less than her, leading to frustration as she felt her learning was hindered, describing her participation as forced and inauthentic. She would feel frustrated that she was held back by her group instead of trying to get through the in-class worksheet.

Second, the relationship with the instructor also affected their engagement. Ashley had a positive perspective of her instructor, appreciating their approachability and interactive teaching style, which significantly contributed to her active engagement. Ashley valued how her instructor structured their class time and the interactions between students. Meanwhile, Beth had less positive feedback, expressing frustration with the instructor's tendency to go on tangents and over-explain to the point of unhelpfulness, as well as perceived inefficient use of class time, leading to suboptimal engagement, despite acknowledging the instructor's care for students.

Comfort with the Mathematics Content

Something that was relevant for many participants in the study was how engagement shifted depending on the students' comfort with the topic discussed in the course. For context, the first part of the class focuses on functions in general (equations, graphs, polynomials), the second on exponential and logarithmic functions, and the third on trigonometry (angle measures, arcs, and trigonometric functions). Both Ashley and Beth shared that they struggled much more in the first part of the class but felt more comfortable with some of the latter topics. While the reasons behind their comfort levels were different, both noted that engagement would decrease a bit in level or intensity when they felt more comfortable with the content and increased when they struggled with the content.

Although Beth and Ashley experienced a similar relationship between Precalculus topics and shifts in their engagement levels, there was a clear distinction between how Beth and Ashley felt about their own conceptual understanding of the material. On one hand Ashley was thrilled that unlike her time in high school, she was finally getting the "why" behind mathematics in Precalculus at the university. She gave an example of finally understanding the unit circle and even why it was called the unit circle. Meaningful engagement in the course was paying off for

Ashley. On the other hand, Beth shared that her engagement in this class was more about studying and practicing procedures. She shared that despite her comfort with the content (especially trigonometry), she believed a lot of it was still from her time in high school. In contrast to Ashley's unit circle, Beth shared that she could solve problems involving co-terminal angles, but she still didn't know what they were.

Grades as a Factor Informing Engagement

While it is common for educators to talk about the role of formative assessment in giving feedback about student learning and their own teaching, it was interesting to see how the study participants talked about adapting their engagement using grades as feedback. This point is related to the previous idea of comfort with the content: for students their grades are an indicator of sorts whether they grasp the content or not. This informed their next steps: lower grades signaled to them that they need to do more, pay more attention; higher grades signaled that they have some level of understanding and thus can shift their energy towards engaging in other things. This was also highly related to the students' busy college schedules, when they are juggling multiple demands on their time and energy towards engagement.

One instance when grades informed students' engagement manifested for Ashley and Beth during the time leading up to Test 1. Ashley was not doing well on quizzes in the class so far. In fact, her first quiz she got a 6.5 out of 12 and the instructor told her class that anyone who got a 6 or below on the quiz should consider withdrawing from Precalculus or enrolling in a support class. Ashley's ongoing struggles with quizzes impacted how she felt about her understanding of the material. She even shared that she thought she knew the content well enough before the first quiz, but the grade proved otherwise. These struggles led Ashley to increased engagement and a lot of preparation for the first test of the semester, resulting in her getting a 90.5 out of 100 on it. One must note that the highest point in the entire engagement graph for Ashley in Figure 1 was around Test 1. Beth had quite the opposite situation compared to Ashley. She felt confident in her knowledge of the material, averaging 95% on her quizzes. She wasn't as engaged in the course leading up to Test 1, on which Beth earned a 77 out of 100.

Discussion

Many of the factors identified as impacting students' engagement in this study are in line with extant literature on mathematics engagement. In particular, the value of student-teacher interactions has been identified as having a great impact on students' engagement (e.g., Barnes, 2019; Durksen et al., 2017; Lin et al., 2018). Beth's negative experiences of engagement with her instructor's in the moment feedback have also been noted in research on flipped mathematics classrooms (Cevikbas & Kaiser, 2022). Previous research has also noted the role of the physicality of the learning environment (e.g., Imms & Byers, 2016; Waldock et al., 2017).

Simultaneously some of the findings have the potential to expand our understanding of how students experience engagement as it relates to their comfort with course content. This is especially relevant for early-college mathematics classes like Precalculus, where the material is not new for students and their engagement might shift differently compared to courses where material is mostly new (Amman, 2022). Understanding how college students use grades as formative feedback for regulating their own engagement can prompt us as a research and teaching community to think more critically about how assessment tools are used in courses like Precalculus. Moreover, this can promote highly needed conversations about further soliciting college students' descriptive experiences of mathematics gatekeeper courses as it relates to their motivation, engagement, and self-regulation.

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