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Contextualized Self-Regulated Learning: Chemical Engineering Students' Learning Experiences in a Materials and Energy Balances Course

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Abstract

The transition into an engineering discipline via introductory discipline-specific courses can be challenging for many undergraduate students. These reasons include the demanding nature of engineering coursework which can be exacerbated by the documented equity and inclusion issues. Chemical engineering students are often introduced to the curriculum through the materials and energy balances (MEB) course. Because students' performance in the MEB course significantly impacts their pathways into or out of the chemical engineering program, it is essential to create more equitable learning environments and consider how students develop the relevant skills needed to succeed in the MEB course. This paper reports on the initial development of a contextualized conceptual framework to describe how students monitor and control their strategies towards their intended learning goals in the MEB course based on the self-regulated learning (SRL) framework. We conducted two focus groups with students enrolled in the MEB course in Fall 2021. The research participants described their learning experiences in the MEB course using a visual elicitation tool (a rich picture). Excerpts from the focus groups transcripts and research artifacts (i.e., rich pictures) were used to answer the research question, "What types of self-regulated learning skills are used by students in the MEB course?" The rich pictures and focus group transcripts were coded using directed qualitative content analysis (QCA). We identified that *Action and Effort*, *Understanding*, and *Motivation* are necessary components of students learning experience in the MEB course. In addition to the cognitive and behavioral strategies, motivational learning strategies are essential for students' development and success in the MEB course. Our results indicate opportunities to support the development of effective regulation strategies towards intended learning goals. It is also necessary to explicitly teach these skills, rather than relying on inconsistent learning experiences and processes.

Background and Objectives

Many engineering students often struggle with the entry-level courses in their discipline. Several reasons have been cited for this struggle, including increasing topic complexity, complex problem-solving methods compared to rote algorithms they utilized in previous classes, and learning new discipline-related jargon [1]–[4]. In addition to these issues, engineering often does not explicitly teach the necessary skills and expectations for success [5]. This *hidden curriculum* influences the students' learning environments and outcomes. Especially for systemically minoritized students (i.e., women, Black, Indigenous, Latina/o/x students, and at the intersections of these identities), the exclusionary norms in engineering and the absence of necessary strategies for learning have led to inequitable outcomes [6]–[11]. This perceived and apparent complexity of introductory engineering courses and sociocultural factors in the immediate classroom environment and broader educational context shape students' learning experiences [12]. Other scholars have noted that the transition to discipline-specific courses in the second year is often the most challenging period of the undergraduate experience [13]–[17] and often when students leave engineering [18].

The introductory chemical engineering course is the materials and energy balances (MEB) course and a gateway to the chemical engineering curriculum. Performance in the MEB course significantly impacts students' degree pathways into or out of the chemical engineering program [3]. Therefore, it is crucial to investigate how to support students' development of the skills needed to succeed in this course and teach this hidden curriculum—the unofficial, implicit messages that students receive about disciplinary perceptions, values, and expectations [19]–[21]—to students in ways that improve outcomes for all students.

Theoretical Framework

One promising theory for promoting student learning and equitable academic outcomes is self-regulated learning (SRL). SRL is an active and dynamic process where students monitor and regulate their learning targets [22], [23]. Self-regulated learners activate their prior knowledge, motivate themselves, plan, and set learning goals (*forethought, planning, and activation phase)*. Then they continuously monitor their progress towards their goals (*monitoring phase*) and adapt their learning strategies to meet these goals (*control phase*). At the end of the specified task, learners evaluate their performance and consider how to approach a similar task in the future (*reflection and reaction phase*). The phases of SLR can be applied to four areas of regulation: cognition/metacognition, motivation/affect, behavior, and the learning context in which students are situated. **Error! Reference source not found.** organizes this framework into four stages and areas of regulation. SRL is relevant in the MEB context where chemical engineering students set learning goals toward new discipline-specific content, including forming peer groups or networks, interacting with chemical engineering professors, and developing appropriate learning approaches.

	COGNITION	**MOTIVATION/AFFECT**	**BEHAVIOR**	**CONTEXT**
FORETHOUGHT, PLANNING, AND ACTIVATION	Set task-specific goals Prior knowledge Metacognitive knowledge	Goal orientation* Efficacy judgments** Ease of learning (EOL) judgment/Task difficulty Task value Interest	Plan time and effort Plan self-observations	Perceptions of task Perceptions of context
MONITORING	Metacognition***	Monitor motivation and affect	Monitor effort, time use, need for help Observe behavior	Monitor task and context
CONTROL	Select and adapt strategies	Select and adapt strategies	Increase/Decrease effort Persist/Give Up Seek Help	Change or renegotiate task Change or leave the context
REACTION AND REFLECTION	Evaluate performance Attributions****	Affective reactions Attributions****	Make different choices	Evaluate task Evaluate context

Table 1: Conceptual Framework for SRL (Adapted from Pintrich, 2000)

Note: *Reason for engaging in academic tasks; **Beliefs about ability to perform a task; ***Thinking about thinking; ****Deducing the cause of performance or motivation/affect.

This paper reports on the initial development of a conceptual framework, starting with the general SRL psychological theory and contextualizing this theory to an introductory chemical engineering course to determine how chemical engineering students navigate their learning in the course. This framework will be helpful for chemical engineering education researchers studying how students learn new chemical engineering concepts and stakeholders interested in understanding how chemical engineering students navigate the discipline. Our results were informed by qualitative data from an ongoing research study. We used excerpts from the focus groups transcripts and research artifacts (i.e., rich pictures) to address the research question, "What types of self-regulated skills are used by students in the MEB course?"

Methods

Course Structure and Modality

The MEB course is an introductory chemical engineering course for chemical engineering students at Purdue University, where students learn materials balances, energy balances, and thermodynamics concepts. To pass this course, students must earn a C grade or higher. The final grade in the class was determined using weekly homework assignments (15%) and four exams (85%). In Fall 2021, this course was offered in-person for the first time since the COVID-19 pandemic. Previously, this course was restructured from three weekly lectures and recitation sections to a flipped learning format. Students watched content videos before coming to class and engaged in active learning and problem-solving in class [24]. Although the modified course structure was maintained in Fall 2021, due to administrative decisions and COVID-19 health concerns, the class was split into two, with one group of students attending the Monday session and the second group of students attending the Wednesday session. The instructional content was recorded so that all students had access to the lecture content. All students were also required to attend a weekly virtual recitation group hosted by the co-instructor to practice example problems.

Positionality Statement

We provide information on our prior experience and positioning to acknowledge these influences on this research study [25]. Adaramola is a chemical engineering graduate student interested in understanding how students learn chemical engineering concepts and developing tools to support students' understanding of these concepts. Her perspective on how students navigate the introductory chemical engineering MEB course is informed by evidence from literature and her personal experience as an undergraduate student (in the same chemical engineering program). Godwin is an associate professor in engineering education and chemical engineering. Her work focuses on how diverse students develop identities as engineers and how they experience the engineering education ecosystem from high school, through college, to their early careers. Her work focuses on multiple identities of becoming an engineer and how this identity is incorporated with gender, race/ethnicity, first-generation college student status, etc., and how engineering roles may be raced or gendered. Godwin has taught the MEB course in previous semesters and has developed curriculum and pedagogical innovations to improve identity, motivation, belonging, and inclusion in the classroom.

Data Collection

To understand how students learn in the MEB course, we conducted two focus groups with students enrolled in the course in Fall 2021. There were five participants in the first group and three participants in the second group. Each focus group lasted approximately 2 hours. To build rapport early in each focus group, the participants discussed the factors that influenced their choice to major in chemical engineering. Then, we introduced the concept of a rich picture and asked the participants to describe their learning experience in the MEB course using a rich picture as an elicitation tool. A rich picture visually represents a particular event or system based on the creator's perspective [26], [27]. After the participants completed the task and narrated their pictures, we led them to discuss their learning experiences in the MEB course, focusing on their challenges, frustrations, resource usage, and motivations. This paper reports on the participants' visual representation and verbal description of their learning experience in the MEB course. The rich pictures were converted into digital copies using software (Amadine and Microsoft PowerPoint). We recorded the group discussion during each focus group and transcribed the audio recordings using transcription software (otter.ai and Microsoft Word Diction). After the initial transcription, we crosschecked the transcripts for accuracy and anonymized the data using pseudonyms to protect the research participants' identities. The institutional review board approved this study at Purdue University under IRB-2021-1176.

Participants

We recruited the research participants via email from the students enrolled in the MEB course in Fall 2021. After six recruitment emails and 21 initial responses, we conducted two focus groups, a virtual focus group (through Zoom) and an in-person focus group. The focus groups took place later in the semester to ensure students had "settled into the rhythms" of the class. The format of each focus group (i.e., in-person or virtual) and the number of participants were primarily influenced by participants' availability and preferences. We attempted to prescreen interested participants using their self-reported demographics to gather a representative sample of students in the course and create focus groups. Still, we had few Black, Latino/a/x, or Indigenous students indicate interest. This result is partially due to the institution's composition, a predominately white institution, but also may be due to other demands on students' time. We discuss this limitation in the limitation section of this paper. Table 1 details the (self-reported) demographic information for the focus group participants.

	PSEUDONYM	RACIAL/ETHNIC IDENTITY	GENDER IDENTITY
FOCUS GROUP 1 (VIRTUAL)	Jubilee	White	Woman
	Claire	White	Woman
	Zara	White	Woman
	Logan	White	Man
	Justin	White	Man
FOCUS GROUP 2 (IN-PERSON)	Andrew	White	Man
	Ian	Asian	Man
	Yohan	White	Man

Table 1: Self-Reported Demographic Information (Overall demographics*: Men = 106 and Women = 60)

Data Analysis

Directed or deductive qualitative content analysis (QCA) is appropriate for extending a conceptual framework or theory [32]. This method uses a deductive approach to qualitative analysis where you start with an existing theory or framework and utilize data to either support or build upon that framework [28]. We used a directed (QCA) to identify prominent themes in the visual representation and verbal description of the rich picture [27]–[29]. The initial codes reflected the language of the participants (i.e., "*getting it*," "*lightbulb moment*," "*Aha*," etc.) and our interpretations of the data. Once individual codes were generated from each student's rich picture and narration, the second coding round was conducted to collapse these themes into common themes across participants and focus groups. Finally, these themes were mapped to the regulation strategies from the SRL framework to understand how student strategies for SRL manifest in this introductory course and provide contextualized ways to understand how to better support these strategies in student development.

Results

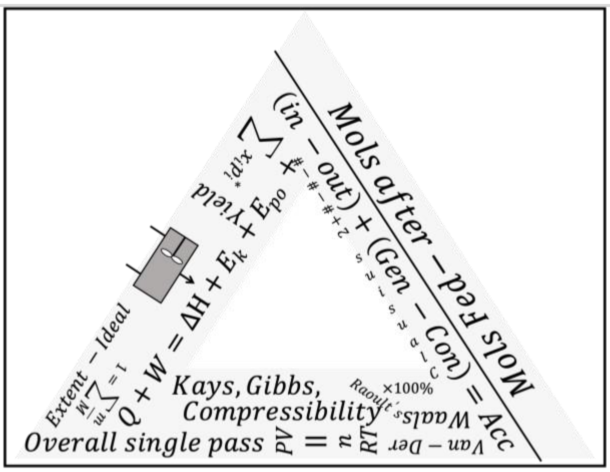
The following results present the rich pictures and individual themes that describe each student's learning experience in the introductory MEB class. Also, excerpts from the transcripts were included to explain the meaning of each diagram in the participants' own words. While we identified six themes, the themes *Action and Effort*, *Understanding*, and *Motivation* emerged as particularly important for students' development and success in this class. These themes are summarized below.

- *Understanding* – This theme categorized instances when students experienced understanding or lacked understanding.
- *Motivation* – This theme categorized students' emotional and motivational regulative processes. It included positive affect/motivation like interest in the MEB topics and confidence after solving a challenging problem. It also included negative affect/motivation, such as feeling discouraged or overwhelmed by negative feedback (i.e., bad grades).
- *Course Complexity* – This theme categorized instances when the students mentioned the challenging nature of the MEB course.
- *Action and Effort* – This theme refers to students actively monitoring, controlling, and reflecting on their behavior in the MEB balance class. It included activities like practicing example problems, seeking help, catching up after falling behind, adapting to a new learning approach, and persisting in the face of challenges.
- *Time Management* – This theme refers to students' use of their time towards the MEB course, primarily when the MEB course competes for time with the students' other classes, job commitments, and social lives.
- *Social Interactions* – A theme for students' positive and negative experiences while interacting with their peers, the TAs, and the course instructors.

Rich Pictures: Focus group 1

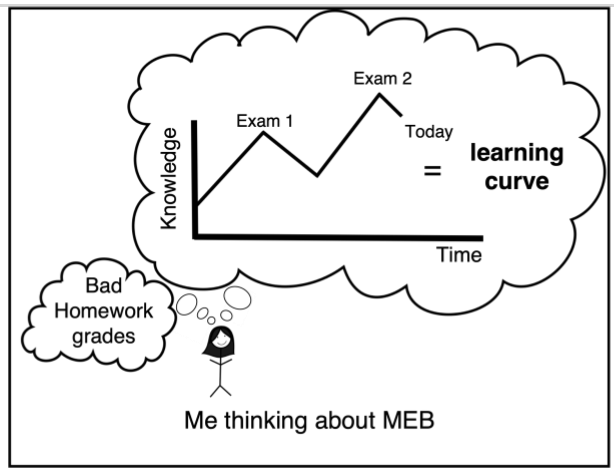
Justin's rich picture (Figure 1) illustrated how he managed the complex topics in the MEB course. Although he often felt initially confused learning concepts in the course, as he studied for the course exams, he was able to clarify the key ideas and relationships. He chose to represent this process of moving from confusion to understanding by organizing a chaotic mix of chemical engineering concepts into a triangular structure/diagram. In the narration of his rich picture, he also mentioned how he had not made social connections in the MEB course.

> *My experience with this class has been weird. It hasn't really been a social class for me. I've made friends in other ones, but this is a class where I just haven't had a lot of time to focus on it/ busy with other things. At times, it seemed very confusing and what's happened twice so far is that I got rather confused with the material and then it became time for the exam and I studied and looked at it all over and then, it all just seemed clear and made sense. So, I just took all kinds of equations and various (terminology) we've been learning and aligned them all in a chaotic manner that forms the clear shape of a triangle or arguably a delta… which is something that I actually understand quite well relative to how I felt immediately after learning other things.*



THEMES
Action and Effort
Course Complexity
Time Management
Understanding

Figure 1: Justin's Rich Picture and Themes



THEMES
Action and Effort
Motivation
Understanding

Figure 2: Jubilee's Rich Picture and Themes

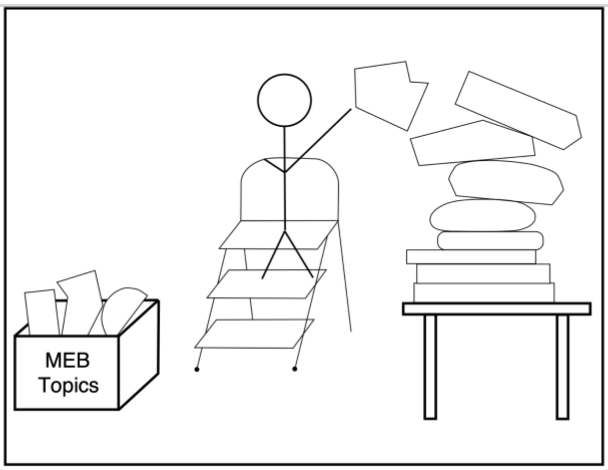
Jubilee described her learning experience in the MEB class in terms of the course deliverables (exams and homework assignments), her perceived knowledge about the course content, and time (Figure 2). Her "learning curve" was a continuous process that oscillated between "getting it" or understanding (defined by increasing knowledge) and "not getting it" or confusion (defined by decreasing knowledge). She discussed feeling reassured and confident closer to the exams due to practice exams and good exam grades but feeling discouraged due to poor homework grades.

> *I think I had a similar thing to* ***Justin*** *because I feel like I don't really get it, and then right before the exam I get it. It's like I don't know, maybe just the practice exams really helped me, so I drew myself thinking about how I used to not get it, and then I did… Another thing I had on is sometimes I just do really bad on the*

homework it's kind of demoralizing and it makes me think that I don't understand any of it and then comes the exam and I do great on the exams…

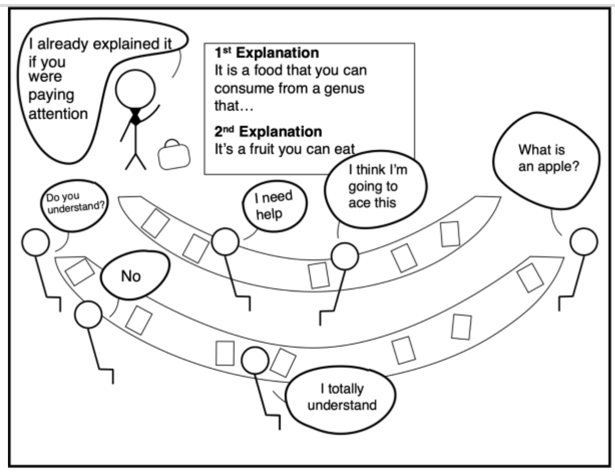
Zara drew a stick person balancing on a ladder and stacking increasingly complex shapes (MEB topics) to illustrate the increased difficulty of the course content as the semester progressed (Figure 3). With sustained and intentional effort, Zara was still able to keep the precarious tower from toppling over despite her feeling that the course was challenging.

> *I feel my experience with this class is that in the beginning the first material of exam one made total sense to me, totally clicked in my head. Exam 2 was kind of **eh** and then the stuff we're doing now I'm not really lost but I'm definitely more confused than I was before, so I drew myself stacking pieces up on a table. The pieces are just getting more complex and it's harder for me to balance them to get the structure to stay up, but I'm still managing to do it. It's just harder now than it was before.*



THEMES
Action and Effort
Course Complexity
Motivation

Figure 3: Zara's Rich Picture and Themes



THEMES
Action and Effort
Course Complexity
Motivation
Social Interactions
Understanding

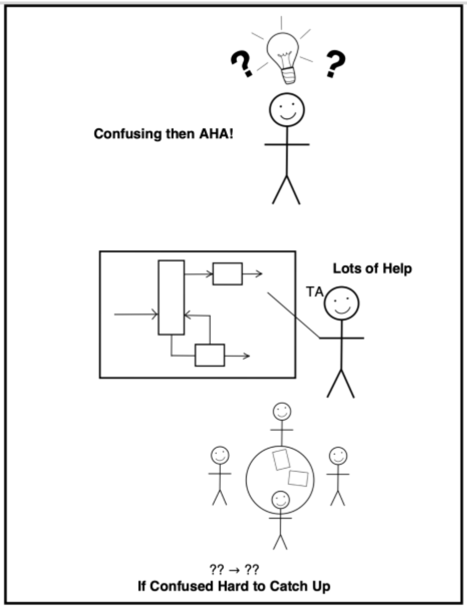
Figure 4: Claire's Rich Picture and Themes

Claire situated her rich picture in the physical classroom environment and primarily focused on her perceptions of the interaction and dynamics between the students and the instructor (Figure 4). In her rich picture, some students were confused and needed help, others understood, and one was distracted. In her verbal description of her image, Claire emphasized a divide between the students who "got it" and those who did not. This perspective reflects her efficacy beliefs or beliefs about her and other students' abilities to meet the course expectations based on the assigned tasks and assessments [23]. Also, she included the course instructor standing in front of the classroom (facing the students) beside a board. On the board, the instructor provided two types of explanations. The first explanation represented a situation where the instructor overexplained a concept and provided too much information to be meaningful, while the second example was simple and easy to understand.

> *I have also been like* ***Zara****… The first stuff was easy like 'okay sig. figs (significant figures) cool' and then it got to adding in work, heat, dew point, and other such things and I just got really confused… So, I drew a picture of a lecture hall format, with a couple people in it and, like some of the people are saying 'I don't understand' and then some of the people are saying 'I understand, I'm totally going to ace this exam.' I feel in this class there's people who understand and people who don't and to me there's no in-between because (for) the people who don't understand it's harder for them to take the exam because it just keeps going and going and going and you don't have a lot of time to catch up, especially if you don't have that Aha moment. And then the people who totally understand, they're like 'Oh yeah like mass, volume… I totally get all this like it's so easy.' …I also drew that situation where one person asked (the) professor a question and then he said 'I literally just explained this' and then he went back through it and it made more sense the second time because he kind of dumbed it down…*

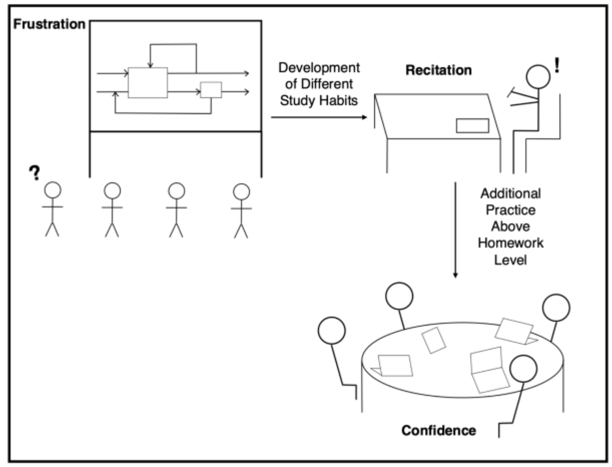
Like other participants, Logan described moving from a state of confusion (represented by the question marks in Figure 5) to understanding (represented by the lightbulb). In another scenario, he drew a teaching assistant (TA) standing before students to represent his support from the TAs and his peers in the MEB course. In addition to peer group support, he mentioned many resources available to support students in the MEB. Finally, he acknowledged that despite the available resources in the course, it was challenging to keep up with course content after falling behind.

> *The first thing I drew was me with a bunch of question marks and then a light bulb and that represented how it's been really confusing and then all of sudden it clicks and it all comes together. Another thing I drew was a bunch of people, together with a TA (teaching assistant) and that represents how I feel the TAs and working with other groups and with other people have been a lot of help to me. When you're on top of the content there's a lot of resources to help you, but then I drew a last thing which represented if you're confused it's hard to get caught up because, once you get past the material there's no solutions to the homework or anything really, and so it kind of feels like once you're lost, you're lost until you get that Aha moment.*



THEMES
Action and Effort
Course Complexity
Social Interactions
Understanding

Figure 5: Logan's Rich Picture and Themes



THEMES
Action and Effort
Motivation
Social Interactions
Understanding

Figure 6: Andrew's Rich Picture and Themes

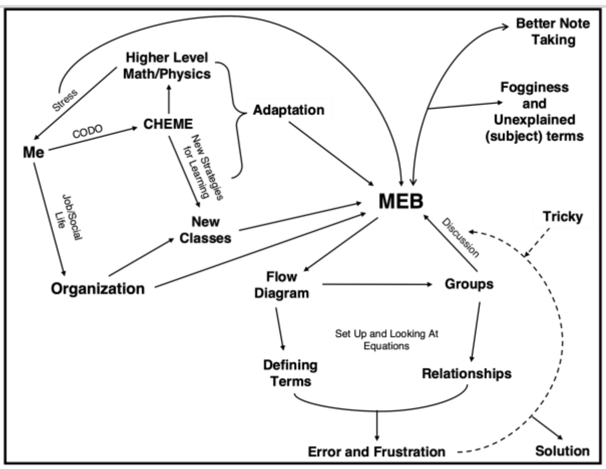
Rich Pictures: Focus Group 2

Andrew described his learning experience in three distinct stages: frustration, adaptation, and confidence (Figure 6). In the first stage, he recalled a particular incident where he felt frustrated and unsupported while working on a homework problem with his group members. In the second scene, Andrew changed his approach to the class by adopting new study habits and attending office hours. In the final stage, he drew a group of students around a table to represent finally feeling confident in his ability to succeed in the class.

> *At first (we) were working on the second homework problem and I remember (we) couldn't do it, we couldn't figure it out. We were struggling to solve a lot of the problems and I remember at that time I felt really frustrated with not being able to see the example problems worked out and feeling like there wasn't enough resources for me to succeed in the class. I moved more towards what (I'd) call the second (stage). I developed different study habits, I went to office hours more, which I hadn't really done very much in many previous classes and with that came a period of time (when) I started getting things put together a lot better and where I started getting really good at solving these problems and figuring stuff out. The stage that (I) would say I'm in now is I'm pretty confident in my abilities in the class… even though I did find this week's homework very difficult I'm definitely confident that I'll be able to master this material and do well (on) the next exam.*

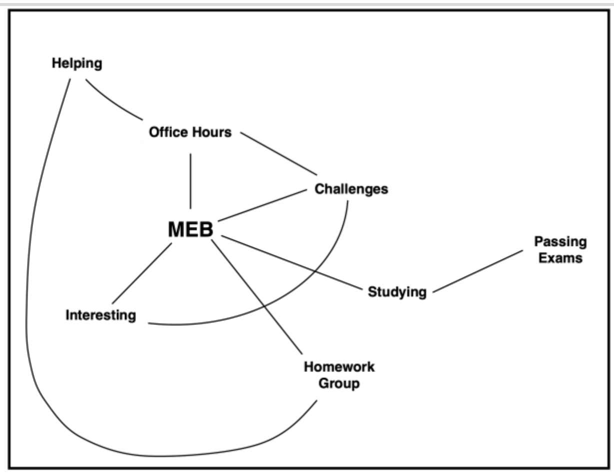
Ian's learning experience in the MEB course was unique because he switched to chemical engineering from a science major. In his rich picture (Figure 7), he described his transition into the MEB course as an iterative process. He adopted a different "learning approach" to better suit the expectations of the MEB class, which included taking better notes, working, discussing in groups, and practicing more problems. Despite the errors and frustration involved in this iterative problem-solving strategy, Ian developed confidence in his ability to succeed in the class. In addition to social interactions within the classroom, he also indicates balancing the MEB course with his job and social life.

> *This (*Figure 7, top left*) is me transitioning into the class. I had to adapt and be more organized but then I found out that wasn't quite enough. So I started taking better notes … it became a really iterative process. I had to retrain myself to think in a different way. (I) started drawing a lot more flow diagrams, (writing out) every single part of the equation, (sharing and discussing) with (my homework) group…it was just an iterative process. But it (reached) a point where there was a light bulb moment and where I (started) to understand 'Oh this is difficult because I'm not learning right'. (This iterative process) led me to error and more frustration until the (flow diagrams, equations and) relationships made sense and that's how (I got) to a solution. So like* ***Andrew,*** *I had to adapt my learning style to better suit what I was learning and be more confident in my answer but there was a period of time where I was frustrated (because) I didn't know what I was doing.*



THEMES
Action and Effort
Course Complexity
Motivation
Social Interactions
Time Management
Understanding

Figure 7: Ian's Rich Picture and Themes



THEMES
Action and Effort
Motivation
Social Interactions
Understanding

Figure 8: Yohan's Rich Picture and Themes

Yohan's rich picture (Figure 8**Error! Reference source not found.**) captured the different resources he used to navigate the challenges he faced in the MEB course, including studying (by himself), solving problems with his homework groups, and attending office hours. Despite the challenges, he was generally interested in and motivated by the MEB course.

> *Most of the things that I remember are interacting with my homework group in office hours to cover the homework (and) studying separately. I might get frustrated but if I work through (the homework) enough I'll start understanding everything and completing all the problems that I do. I think that all of the work that I've done (in) this class is challenging but I know that if I go to the right places and put in the effort that I will be able to understand it and do it correctly.*

We mapped the six themes identified in the results section to the regulation strategies in Table 1. From the rich pictures and verbal descriptions, we deduced that the participants' goal or target in this course was to earn good grades (i.e., practicing problems on the homework and practice exams and performing well on the individual exams). The participants discussed setting goals, monitoring their cognition/metacognition (e.g., realizing when they were confused), and selecting and adapting helpful learning strategies (e.g., practicing problems) [23]. These strategies are examples of cognitive and metacognitive learning strategies and relate to the identified themes of *Understanding* and *Action and Effort*. There is weak evidence supporting participants' use of metacognitive learning strategies and performance evaluation beyond monitoring homework and exam grades. The participants' motivational and affective strategies include efficacy judgments, perceptions of the difficulty of the tasks, awareness of their emotional state (e.g., frustration, confidence), and emotional reactions to activities and assessments in the MEB course[23]. These strategies relate to the *Course Complexity* and *Motivation* themes. The behavioral process and decisions included managing (planning and monitoring) time and effort, seeking help, increasing or decreasing effort, and persistence [23]. There is evidence that participants were able to reflect on their learning goals and make different behavioral choices to accomplish their goals better (e.g., talking to peers, attending office hours). These strategies relate to the themes of *Time Management*, *Action and Effort, and Social Interactions*. Finally, the contextual processes included participants' perceptions of the task and context (classroom structure and context), awareness of classroom norms and instructor behavior, and evaluation of the task and context [23]. These strategies relate to the *Social Interactions* theme. These results identify learning strategies from the SRL framework relevant to learners in the MEB context.

Discussion

We were interested in identifying the specific learning strategies chemical engineering students used to set goals, monitor their progress towards those goals, and adjust their learning in the introductory chemical engineering course. In this course, students are introduced to (chemical) engineering problem-solving methods, where they require new strategies to succeed compared to the skills they employed in introductory science and mathematics classes [30], [31]. Nelson and colleagues [32] indicated that most (83%) first-year engineering students adopt learning strategies that negatively impact their learning. Other work has demonstrated that when students do not develop learning strategies that move beyond surface-level understanding (i.e., memorization), they are less likely to persist in engineering [33]. Developing these problem-solving skills was a challenging and non-linear process for most students. The focus group participants described iterative, complex learning journeys, including practicing problems, seeking help early, managing complex and increasingly challenging topics, managing time, and making changes based on feedback from assessments. Our results indicate opportunities to foster and discuss effective classroom cognitive and behavioral regulation strategies for learning in this introductory course. Instead of regulating their learning around smaller, well-defined learning goals, our results suggest that students set broad learning goals (i.e., earning good grades on homework and exams). It would have more manageable for students to regulate their learning around achievable goals earlier in the semester and then shift to focusing on these larger goals closer to the event [34]. Classroom instruction and utilizing explicit learning objectives can help students regulate their learning in this class [5]. Students will benefit from being taught the hidden curriculum of SRL strategies that lead to the desired learning outcomes alongside the explicit learning objectives in the MEB course. MEB instructors can encourage students to set learning goals based on their interests and periodically reflect on these goals by providing them with opportunities to do so within the classroom context [1], [18], [23]. Instructors can also discuss how students can actively monitor their progress in the course and adjust quickly. For example, instructors can inform students about the approximate amount of time they should spend on homework problems each week so that students can monitor their learning progress outside of feedback from homework and exam grades. In addition to providing monitoring strategies, instructors need to mention that each student's adjustment period will look and feel different to normalize the struggles and feelings of frustration students face as they monitor and adjust their learning approaches [6], [12].

Students also relied on their peers and social network to succeed in the MEB class. In the focus groups, the participants mentioned working with their peers, reaching out to older chemical engineering students that have passed through the course, attending instructor and TA office hours, and utilizing online resources to support their learning in the MEB course. Access to some of these resources may be challenging for students who do not have the same networks and navigational capital as their peers (i.e., systemically minoritized students) [5]. Considering students' interactions and perceptions within the classroom environment is most evident in Claire's rich picture (Figure 4). She perceived a distinction between students who get it and those who don't. The instructor can facilitate discussion of learning as a developmental process rather than a binary outcome [35], [36]. In addition, regulating context is particularly important when considering an introductory course where students must adjust their expectations and classroom norms to that of the instructor [29]. It is vital for chemical engineering instructors to intentionally create these opportunities within the classroom to create more equitable and inclusive learning environments.

Limitations

We also note some limitations of this work that we hope to address in future work. Our focus groups only represented a small fraction of the student population in the MEB course and did not have representation from Black, Latino/a/x, and Indigenous students. We will conduct more focus groups focused on Black, Latino/a/x, and Indigenous students in the future to better represent experiences and the (explicit and implicit) messages that students receive in the MEB course related to their SRL and success. We will recruit students from these groups across different semesters to overcome the small recruitment pool. These planned focus groups will be essential in developing a conceptual model for SRL in the chemical engineering context that considers students at the intersections of students' gender and race/ethnicity.

Conclusions and Future Work

Apart from cognitive and regulative strategies, motivation and classroom context impact students' learning in the MEB course. Students need to put in the effort, manage their motivation, and adopt appropriate strategies to support their learning goals in this class. Our results indicate opportunities for instructors to foster and discuss effective regulation strategies in the classroom for learning in this introductory course. Introductory courses present many opportunities to equip students with relevant learning skills to succeed in the chemical engineering curriculum and teach these skills explicitly rather than relying on inconsistent experiences and processes for students to develop these self-regulation strategies independently. We suggest that instructors carefully consider the often-implicit messages and the hidden curriculum and instead be explicit about the critical SRL strategies that will enable student success.

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