Unpacking High School Students' Motivational Influences in Project-Based Learning

Prateek Shekhar, Heydi Dominguez, Pramod Abichandani, and Craig Iaboni

***Abstract*—*Purpose:* The presented study was conducted to unpack high school students' motivational influences in engineering/computer science project-based learning (PjBL), using the attention, relevance, confidence, and satisfaction (ARCS) model of motivation as a conceptual framework.**

***Methods:* A qualitative research approach was used with student focus groups as the data source. A total of six focus groups with 32 student participants was conducted. The students were enrolled in high schools located in four different states in the U.S. The qualitative analysis of transcripts was performed using first and second cycle coding methods.**

***Findings:* The findings show that student motivation is nuanced in regard with attention, relevance, confidence, and satisfaction. The findings identify research-based strategies for fostering student motivation, such as implementing learner-focused scaffolding in PjBL environments, improving the relevance of the classroom content with the real-world context that students have experiences in or are knowledgeable about, and focusing on stimulating intrinsic motivation in addition to extrinsic rewards.**

***Conclusion:* The findings provide support for the comprehensibility and utility of the ARCS model of motivation in high school engineering/CS education, and more importantly empirically unpacks what the model factors mean from students' perspective. Practitioners may use these findings to inform the design, development, and implementation of PjBL in high school settings.**

***Index Terms*—Engineering education, motivation, precollege, project-based learning (PjBL).**

I. Introduction

EFFECTIVE engineering education does not only centralize on the delivery of essential knowledge but also on students' motivation since it plays a significant role in enabling student engagement and successfully achieving the targeted learning outcomes [1]. In psychology, motivation is an important concept that can be defined as a mental state that inspires one's behavior and stimulates the desire to achieve one's goals [2], [3]. In engineering education, majority of the motivation work focuses on student attrition and how it is linked to high student drop-out rates within engineering disciplines [4]. Studies have shown that motivation has a direct effect on academic achievement and have suggested that students with high levels of motivation were actively engaged in courses and achieved better-learning outcomes than those with low levels of motivation [5], [6]. Conversely, lack of motivation can stimulate negative behavior, and is noted as a reason for dropouts among engineering undergraduate students, and graduates leaving their engineering careers [3]. Furthermore, researchers have found that engineering career motivation may be traced back to students' initial years of exposure to engineering which once initiated their motivation to pursue a degree in their field [1]. Thus, it is critical to ensure student motivation is considered when designing educational interventions, particularly in precollege settings where students often gain initial exposure to engineering and/or computer science (CS) education.

In contrast to traditional teaching methods, new teaching methods have been developed for stimulating motivation in student engagement [7]. Particularly, researchers have found project-based learning (PjBL) to be effective in fostering students' motivation, and consequently leading to students demonstrating better participation and teamwork [8]. As a result, PjBL is increasingly being used in precollege engineering education [9] with engineering often being used as a platform for STEM integration [10], [11], [12]. Considering that motivation is a key influencer of students' academic achievements and engagement [13], [14], it is imperative to ensure that the interventions are aligned with student motivation as educators continue to build and implement PjBL interventions in precollege engineering education. The presented study examines high school students' motivational factors to inform the development of effective engineering education interventions.

Furthermore, while conceptual and theoretical frameworks are essential in the advancement of the quality and value of research in any field [15], there is a lack of work using theoretical frameworks, specifically in measuring student motivation in engineering education [13]. The presented study uses the attention-relevance-confidence-satisfaction (ARCS) model of motivation model of motivation as a conceptual frame- work in the qualitative analysis to understand high schooler's motivational factors in PjBL. Several studies have reported the effectiveness of implementing PjBL toward motivation in learning environments by conducting

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post-intervention assessments using the ARCS model of motivation [16], [17], [18], [19]. However, there is a lack of research on the examining what the ARCS model means from an instructional design perspective, prior to an intervention. It is argued that pre-intervention examinations are as important, if not more, than post-intervention studies. The research unpacks high school students' motivational influences by examining the research question: What factors inform students' motivation when engaging in engineering and CS PjBL environments?

II. Background

Motivation theories are used to understand the process that enables students to choose and continue to engage in activities [20]. However, motivation is a complex and multifaceted topic, which is demonstrated by the coexistence of several theories, and their nuanced applications in different research contexts [21], [22]. One of the commonly used motivation theories is the expectancy-value theory, which argues that the motivation to engage in a task is linked to an individual's expectancy for success and satisfaction of value [23]. The expectancy for success refers to one's expectation for being successful. For example, if a student is confident in performing a task, they will typically expect success in their performance. The satisfaction of value refers to an individual's interest and relevance in a specific task, such as a student who finds satisfaction in conducting a project that is relevant to their major of study. While expectancy value theory provides a theoretical understanding of an individual's motivation, the ARCS model developed by Keller provides a structured framework to address student motivation in instructional design contexts. Keller uses the expectancy-value theory as a grounding theory to build the ARCS model focusing more on motivation for curriculum and instructional design.

Building on the expectancy value theory, the ARCS model focuses on the reasons behind students' motivation to engage in a learning activity [16]. Specifically, the ARCS model of motivation focuses on four dimensions of student motivation to understand and address their stimulation levels—in attention, relevance, confidence, and satisfaction—in an educational environment [24]. The ARCS model was designed to provide instructors and curriculum designers with a framework for easier accessibility when developing learning environments that stimulate and maintain students' motivation [25]. The first dimension, attention, refers to getting and sustaining student interest during an educational activity. Second dimension, relevance, reflects on meeting the student's personal needs or goals. The third dimension, confidence, refers to the student's self-perception to succeed in an instructional environment. Finally, satisfaction reinforces accomplishment with internal and/or external compensation, which can consist of personal satisfaction or physical rewards [24], [26]. Overall, these four conceptual dimensions of motivation provide educators with tools to gain a finer understanding of issues related to student motivation. Researchers have often conducted studies adapting the ARCS model into their set of general questions to assess student motivation, or applied generic ARCS-based strategies into their interventions [23]. Instead of developing an intervention based on the generic definitions of presented in the ARCS model, the presented work addresses the lack of research examining what the ARCS factors mean from a students' perspective, which is needed in the first place for thoughtful development and implementation of educational interventions, and consequently in achieving favorable post-intervention student motivational response.

TABLE I
Focus Group Participants

Focus Group	Number of Participants	High School
1	5	Suburban
2	6	Rural
3	3	Urban
4	6	Urban
5	6	Urban
6	6	Urban

III. Methodology

A. Participants

The literature suggests that three to six focus groups are ideal for generating 90% of the themes [27]. Thus, to scope the study, six focus groups were administered online with a total of 32 students from four high schools located in four different U.S. states (Table I). Purposive sampling was used to select the schools such that students are from diverse backgrounds [28], and have exposure to PjBL environments so that they can provide their motivational perspectives and experiences. The included schools were from different school settings (urban, suburban, and rural) based on their geographical location and not the population. It is to note that the focus groups were conducted before developing educational interventions that were implemented in the high schools.

Students in these schools attended classes centered around CS, engineering, and Career Technical Education. All classes used single board computers, such as Arduinos and Raspberry Pis. The classes used the Python programming language to study embedded systems, robotics, and Internet-of-Things technologies. The typical projects included building systems that leveraged Python application programming interfaces (APIs) to interface with proximity, environmental, and motion sensors. Students built systems that used sensor-based logic and interfaced with users via LEDs (mono-colored or multi-colored), liquid crystal displays (LCDs), touch screens, and actuating devices, such as motors and buzzers.

Out of the 29 participants who completed the survey, approximately 69% of the participants identified themselves as men ($n = 20$), and 31% identified themselves as women ($n = 9$). In addition, approximately 41% identified themselves as White/Caucasian ($n = 12$), 34% identified as Black/African/African American ($n = 10$), 10% identified as Asian/Asian American ($n = 3$), 3% identified as being both American Indian/Native American and White/Caucasian ($n = 1$), American Indian/Native American and Black/African/African American ($n = 1$), White/Caucasian and Black/African/African American ($n = 1$), and Hispanic/Latino(a) and Black/African/African

American ($n = 1$). Overall, the student participants were from ages 15 to 18 and were enrolled in a sophomore-junior ($n = 18$), junior-senior ($n = 6$), and an all senior ($n = 5$) engineering/programming class in their high schools. In regard with past CS/programming background, 59% reported previously taking a CS/programming course ($n = 17$), 7% reported taking part in a CS/programming project ($n = 2$), 31% reported participating in both ($n = 9$), and 3% reported no previous CS course or project ($n = 1$).

B. Data Collection

The study was conducted after approval from the institutional review board (IRB). Approvals were obtained through IRB-approved student assent and parental consent forms by the research team. Focus groups were conducted to employ guided and interactional discussions as a means of generating student perspectives on and around their motivation in engineering/CS education projects. All focus groups were held online via Zoom/Webex/Google Meet. The focus groups were audio- recorded and transcribed for analysis and reference. The focus group protocol was informed by the ARCS model and was developed to unpack each of the ARCS factors. The protocol was developed in consultation with a STEM education researcher with extensive experience in conducting qualitative research in K-12 settings. In addition, an external expert evaluated the protocol and provided feedback which was incorporated by the researchers. The focus group sessions were initiated with a brief introduction of the study, where students were also asked to create a pseudonym of their choice to maintain student confidentiality. At the end of the session, students were asked to complete an anonymous survey which collected information on students' demographic and academic backgrounds and asked for any additional comments that students had on the focus group discussion.

C. Data Analysis

Focus group transcriptions were analyzed based on first and second cycle coding methods [29]. Fig. 1 depicts the first and second cycle coding methods. First cycle coding methods involve developing an initial round of codes to build a thorough list of codes representing the data set. Second cycle coding methods are more analytical and involve developing categories that synthesize first cycle codes based on conceptual similarity [29]. Cumulatively, the focus of performing each step is to inductively construct an overall inventory of codes (first cycle) and synthesize the inventory to categorize the list of codes (second cycle). Throughout the analysis, memos were conducted to report notes, observations, and any other interpretive commentary made for each focus group. In the first cycle, in-vivo coding was used to develop an initial codebook. Following the development of the first cycle code- book, second cycle coding was conducted, in which codes were combined into groups based on conceptual similarity [29]. Two researchers engaged in the coding process to ensure inter-rater reliability and ensure trustworthiness of the findings [30]. Discrepancies were identified and resolved iteratively through multiple discussions. To identify the categories that fall under the ARCS factors, each code was labeled

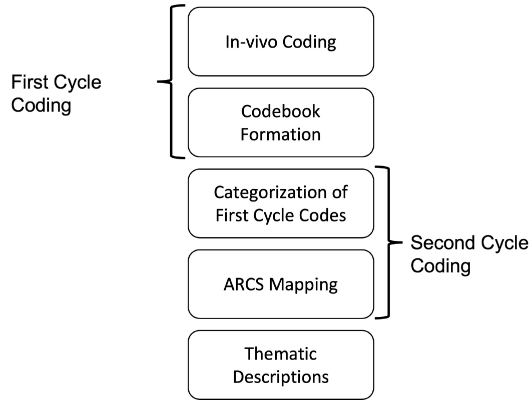

Fig. 1. In the first cycle, in-vivo coding was used to develop an initial round of codes and build a thorough codebook representing the data set. In the second cycle, an inventory of codes was synthesized that grouped first cycle codes based on conceptual similarity. Each code was labeled using a letter from the ARCS acronym. Overarching themes were synthesized to underscore the emergent subfactors in relation to the ARCS model factors.

using a letter from the ARCS acronym to facilitate the process of developing categories in the second cycle. One researcher who was not involved in the coding process served an external check in the labeling process, ensuring the mitigation of researcher biases and strengthening the trustworthiness of the qualitative findings [31]. Finally, overarching themes were synthesized to underscore the emergent subfactors in relation to the ARCS model factors based on the labels assigned in the second cycle coding process.

IV. Findings

The subsections that follow describe the ARCS factors and subfactors emergent from the qualitative analysis of the focus group data. Each subfactor contains themes that provide greater depth and understanding of the topics that emerged within each factor of the ARCS model. The subfactors are depicted in Fig. 2.

When asked a series of questions focusing on expectation of meeting students' personal goals and needs, four subfactors were established. The subfactors pertained to seeking relevance found in students' career, college, project content, and project context. Several themes emerged from each topic. Of note is the fact that career and college relevance was not reported by a subset of students who did not intend to pursue STEM careers. The summary of findings is presented in Table II.

A. Attention

1) Project Complexity/Simplicity: Overall, the students linked projects that were simple and straightforward to capturing their attention when compared to complex projects. For example, reflecting on a project involving light emitting diodes (LEDs), a student stated, "And my favorite project was like, I think it was working with like the RGB LEDs, because they were like, very simple and like straightforward." In addition, students' responses indicated that having clear directions and instructions was instrumental in capturing their attention in the project. Students reported that the lack of clarity in instructions

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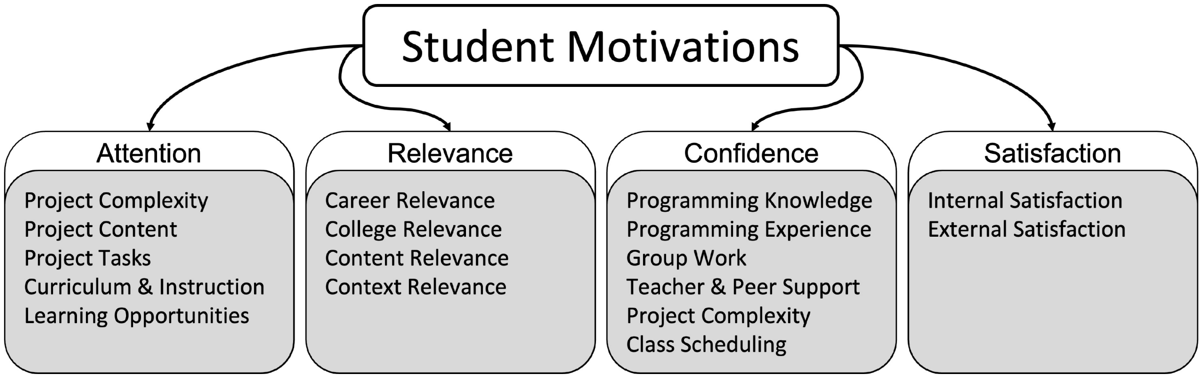

Fig. 2. ARCS subfactors emerging from the qualitative analysis of the focus group data.

TABLE II
SUMMARY OF FINDINGS

Factor	Subfactor	Thematic Description
Attention	Project Complexity/Simplicity	Project clarity with instructions and directions and simplicity of overall project.
	Project Content	Student interest in the Computer Science content, Mathematics content, the combination of both contents, and in STEM related topics.
	Project Tasks	Students' lack of interest in time consuming, repetitive, and tedious project tasks.
	Curriculum and Instruction	Student interest in project-based learning, real world applications, and use of online materials.
	Learning Opportunities	The opportunity to learn capturing student's interest.
Relevance	Career Relevance	Student perceptions of the course's impact on future careers.
	College Relevance	Student perceived alignment between course and students' college interest.
	Content Relevance	Student's resonance with project content.
	Context Relevance	Student perceived correlation between the course and real-world experiences.
Confidence	Class Scheduling	Planning and arrangement of classes with consideration given to academic recesses.
	Group Work	Positive/negative implications associated with student collaboration and collective efforts in a group setting.
	Teacher Support	The degree of assistance and guidance offered by instructors during project-based learning.
	Project Complexity	The degree of challenge and intensity presented by projects in terms of workload and task difficulty.
	Programming Knowledge and Experience	The influence of pre-existing programming knowledge and the influence of its absence on the learning experience.
Satisfaction	Internal Satisfaction	Student satisfaction from intrinsic factors such as learning accomplishments and helping peers.
	External Satisfaction	Student satisfaction from external rewards such as performance feedback and winning a school competition.

and insufficient information lost their attention or interest in learning, as evident in this student response,

"I would get bored whenever instructions weren't completely clear of the problem, we were trying to solve it was more of just taking us through step by step what to do. But I want more of like, you want the program, I want the program to tell me what the program needs to do and not just tell me all the steps to do it."

2) Project Content: Two key themes emerged regarding the project's content. The first theme centered around the CS and mathematics content of the project. Interestingly, student responses varied from being interested in either the mathematics or programming content of the project individually, or in the integration of mathematics and CS. For example, a student interested in programming content said, "I enjoyed the coding that was involved with it and how I could get it to when the temperature change had certain lights come on or have a buzzer go off. I just really enjoyed the implications of it." Along similar lines, a student interested in the mathematics content of the project stated,

"I think it's really useful to understand, like the math that would go into calculating, for example, when something would break how much force is being applied to something, something like that. And I just thought, that if you can sort of apply that to a bigger project, it can be super interesting, because you can sort of predict everything that happens beforehand." Students also reported interest in the integration of both mathematics and CS in their projects. For example, when asked about what aspects of the project captured attention, a student said, "Yeah, just kind of the math and the crossing between like the multiple subjects taking the coding and the math and combining it together in like a map to arrange kind of function."

The second theme involved students reporting their interest in the implementation of engineering and other STEM topics in the projects. Particularly, several students reported interest in seeing more engineering topics implemented in their class project, as evident in this student remark,

"It would be nice, if it like covered more, like more aspects of engineering, because a lot of what we do is just like computer programming coding stuff. We did a little bit of hydroponics, which I liked, because it like delved into more types of engineering. So I feel like if you had a more like, broad spectrum of the different types, you could really decide for yourself, like your favorite and then you could go into that better."

3) Curriculum and Instruction: Overall, majority of the students provided positive feedback in regard with attention and interest for PjBL. In regard with instruction, students highlighted several positive aspects of project-based learning. First, students were positively stimulated by working interactively or with hands-on activities, as stated, "Well, I really like interactive stuff, where we get to work on stuff with like, our hands and design stuff that I like, see it come to life, like where are you printed legs for our drones and like, like we're using them right now." Second, while some students preferred working individually, majority of the students enjoyed working collaboratively in groups, as noted in this student comment,

"I think that the projects that involve like a big group, where everybody works together on one big thing, like kind of what the solar rollers have, I think that would definitely, like be the best kind of way to work out these engineering skills collaboratively, because you sort of have your group mates to fall on to bounce ideas off of. And when everybody works on one big project that comes together a lot quicker."

In regard with curriculum, first, students reported interest in working with real world applications. Many students felt that by implementing real-world applications into the content, the projects stimulated their interests and curiosity to learn more. For example, a student who was interested in adding more real-world applications to the lesson content, stated that, "I feel like the more you add it to real world applications, the more fun it is for people who do not exactly want to do what this program is-based off of." Another student echoed, "So personally, I think one of the most entertaining projects for at least an IoT kit was the joystick, could we add the code for the joystick? And, you know, I like I like, you know, video games. And I think that's interesting to learn how they actually work." Second, students showed disinterest in using only online curricular materials to learn. Several students reported that using only Web-based resources restrained them from absorbing the material in greater depth. For example, a student who reported being displeased by only using videos to learn a new concept stated that, "But just watching the videos was just very, like, I didn't really absorb a lot what was being taught during that. But that was probably the only thing for me." Third, project tasks that were time consuming, tedious, and involving repetitive work, contributed to disinterest among students. Students reported that its "very annoying" when tasks involved "five periods of working," "frustrating" when you are doing it "over and over again," and "boring" when it involved a "lot of note taking." Students suggested that "there could have been a little more interaction" in such tasks, to recapture their attention in the project.

B. Relevance

1) Career Relevance: Several students made connections between their projects and how they were relevant to their career interests, and useful toward their future career. For example, a student noted that their project focused on sustainability was relevant to their career interests, as noted in this comment, "I like the idea of how sustainable even though we didn't grow millions of acres of food with this one and we're not going to feed a whole village you know, but I like how you can scale it up and make it sustainable. And that's why I kind of want to pursue that in the future." Similarly, students appreciated the opportunity to complete technical certifications that could be useful toward their technical careers. For example, a student recognized the importance of becoming certified to fly drones and how impactful it can be in their future career, they stated that,

"And I think that maybe just sort of fitting in more of those certifications stuff. Like I know that in the future, if we get tied for something at the bare minimum, that's recognition for the work you put in, and people maybe if someone hires you in the future, they can look at that and say, Oh, look, this person put in the effort to get that."

2) College Relevance: College relevance was noted as an important motivational factor for high school students as several students recognized how their project experience in class could be useful to them in college. For example, some students underlined the developed skills that would prepare them for their future college experience as described by a student, "And I think that this is the thing that's probably the most relevant to something like a college experience, where whoever's teaching you regarding the project isn't going to be involved in every single part. But you're still there working with either yourself or other people." Furthermore, several students found their college interest coinciding with the content covered in class. For example, students who are interested in majoring in engineering stated that, "And I think if you're majoring in something having to do with engineering, or anything we've really learned in this class, it's really helpful."

3) Content Relevance: Several students felt that the content of their project was relevant and/or useful to the present and future things they wanted to engage in. For example, a student interested in circuits found the microcontroller project useful as it coincides with their personal interest, they stated that, "I wanted to learn more about how to like how to make circuits work. So, I think the wiring dealing with the micro microcontroller and using a breadboard and solder and soldering like everything along elements was useful to me."

Conversely, several students struggled in finding the relevance between their project content particularly in regard with its applicability. For example, a student noted a disconnection between the programming tasks in their project and their relevance to other scenarios, as expressed in this comment, "like we're learning this, but then we're not quite sure how we are supposed to implement that into like, other things, you know, you have this chunk of code. Okay, how do we use this code that we already know? And this other code we already know?"

4) Context Relevance: Several students identified relevant connections between the project content and personal or real-world scenarios. Many students found the project content personally relevant to their day-to-day life. For example, a student used the skills and knowledge gained in class to create a chicken feeder that was used on a day-to-day basis, "I've learned from the programs, such as LocoRobo, I'm able to make the things that I need. I wanted this feeder for my chickens, because I do not have to go to their coop every time to go check their food water. So, because of the abilities I learned in class, I was able to make this into a real-life working product." Along similar lines, a student expressed that the project that involved using LED makes them "see all the implications that has with it, like, it can be used or sound for sensors, it can be used for something basic, just like getting a clock to work or something like that··· you can see how all this code and all these implications can really make incredible things."

C. Confidence

1) Teacher and Peer Support: Several students responded feeling more confident knowing they had teacher support. For example, a student expressed confidence by having their teacher around them, as noted in this comment, "[Teacher] will make you feel confident in here anyway is actually just like having there. Like knowing that, [if] I do not get something, this man will explain it to me." Conversely, several students did not feel great confidence due to the lack of individualized teacher support, a student stated that, "I feel like he is trying to teach everybody collectively like as one and I feel like we cannot get a one on one time." Interestingly, students' confidence also varied based on their personal experience with their peers. While some students were displeased with their experience and compared it to "a double-edged sword" rather than being a positive influence to their confidence, there were several students who felt working in groups increased their confidence and ability to work through a project as they could rely on their partner(s). For example, a student felt confident working on a project with their team and stated the reason why, "I think what boosted my confidence in this class was just like working as a team, and working with other people, and being able to make something that you're proud of··· that's what we boosted my confidence in this class."

2) Programming Knowledge and Experience: Past programming knowledge and experience resulted in increasing students' confidence when performing programming tasks. For example, a student who had prior programming knowledge stated that, "I'm pretty good with most productive projects. But that's because I did I take CS as well, I do Java. And Python is not that much different than Java." Alternatively, students who had little to no programming experience expressed lack of confidence, as stated by a student, "something I wasn't very confident with was the thermal sensor. It was just hard to get it to work properly and the right code was complicated and it just was hard to understand."

3) Reference Materials: Expectedly, students felt more confident when presented with offline or online reference materials. The students felt that reference materials assisted them and enhanced their confidence to work through a project or task, as reported by a student, "But I do think it'd be beneficial to have maybe just like a list of like the basic functions like this is how you create an if statement. This is how you do a while loop and things. Even things, such as like capitals and brackets and things like that can get tricky, so I think it'd be easy to have a little sheet like that. That would just have some information on it."

4) Project Complexity: While project complexity was also noted in regard with attention, project complexity also emerged as subfactor informing students' confidence. First, students reported that the complexity of the project allowed them to work through the challenges which enhanced their confidence, as evident in this student comment,

"I would say the project that made me the most confident as a coder, I would say was our buzzer assignment. Because to get we had to make a song with it··· And so, when once you start getting more buzzer or more buzzers and more buttons, the more complicated it gets. I felt really confident after doing that assignment again, every single button to make different noises and everything and it gave me allowed or showed me that I can do something that seems simple, but when you start coding everything can get really complicated really fast."

Second, students reported that the lack of explanation on math integration hampered their confidence. For example, a student who did not comprehend well the math component of the project, stated that, "So I think that eventually we, you know, in retrospect, I understand how it works now. But when we started off, it was definitely, it felt like a lot of math really quickly. So, I think that was kind of overwhelming." Third, along similar lines, overwhelming project tasks negatively impacted students' confidence, with students feeling overwhelmed by the workload associated with project, as noted in the comment, "These were like multiple pages with interactive assignments that you had to work through. And at the beginning of the year, I'd say that was definitely pretty overwhelming. And at certain points, it was easy to stray off task."

5) Class Scheduling: Intriguingly, scheduling emerged as a factor informing students' confidence. The scheduling issue many students reported was the mandatory school break, which did not academically benefit them as the short pause in their academics slowed down their performance. For example, a student linked their low level of performance with their low level of confidence after returning from an academic break, the student expressed,

"The later lessons was where sort of confidence would go down because if you're gone for a little bit like I for example, I think we were on we went on spring break for a couple of days or it was a week, and we came back, we tried to do the lesson, and I remember that I didn't remember a couple things, and it definitely lowered my confidence because it was a bit of a struggle to try to get back into it and remember exactly what I needed to do."

D. Satisfaction

1) Internal Satisfaction: In regard with internal satisfaction, in addition to students feeling satisfied when they understood concepts or tasks related to the project, several students reported that they were personally satisfied when they learned new things or developed new skillsets, and consequently saw the projects as an "opportunity to learn new things." For example, a student who felt satisfied for the skills developed in class said, "it helps me look at problems differently··· it gives you a different view because I have a different skill set and tools now that I can use that I never had before. So, whenever I see a problem, I know different ways to solve it with different sensors and different ways of coding." In contrast, students reported dissatisfaction when they felt that they were working through a project without learning. For example, a student who felt dissatisfied after completing their assignments, reported that, "But I feel like I'm doing all the assignments and like all the Python and coding and stuff, just to get it done. I'm not doing it to learn the actual, like, science behind everything that I'm doing. I'm just doing it just to finish it and just get a grade on it."

Students reported satisfaction in regard with the learning autonomy associated with working on projects. For example, a student who felt satisfied working through a challenge independently, stated that, "I think it's really nice having independence. Especially when I'm, I'm going to college next year. So, it's nice knowing like, if you can figure something out by yourself, it's just so much more like fulfilling in like, the project. Like, if you can figure it out, and you can research it. It makes you feel like really proud of yourself." Finally, students also felt satisfied in helping other classmates as they worked on the projects, as noted in this student comment, "For me what's really satisfying is like once I grasp the concept and I know it like well, then I can assist my other classmates."

2) External Satisfaction: In regard with external satisfaction, students reported feeling satisfied whenever they received an external reward, such as positive performance feedback or winning a competition. Students who received a good score on a project or assignment demonstrated satisfaction in their work, as reported in this student response, "after completing that and then I scored well on it like made me feel really accomplished because I like we studied for a long time and took a lot of notes and did a lot of practicing."

Similarly, a student expressed satisfaction after winning a school competition, they stated that, "I ended up winning the competition through the ultrasonic sensor and the Arduino that came through the kit that I was fighting with you guys. I was able to make a prototype that comes apart and shows the Arduino battery pack and sonar sensor inside of there and it was a great time." On the other hand, students who received a negative performance feedback did not feel satisfaction with their work, as reported in this student comment, "So, I didn't really feel accomplished about that, because I like watched all the videos, and I did all the work. And I felt like I knew a lot of it. So then when I didn't pass it was, I was pretty disappointed. And it's affected my class experience."

V. Discussion

For effective instructional design, it is critical to take into importance learners' motivational factors to ensure their engagement in the learning process [30]. The study focused on understanding the factors that affect student's motivation to engage in a PjBL environment by using ARCS model of motivation as the guiding conceptual framework. The conceptional framework allows for interpretation of students' motivational factors and assists in the development of instructional strategies for fostering student motivation [23], [26]. These factors involve curiosity and interest, meeting students' needs or future goals, giving opportunity for success and increase in confidence, and reinforcement for their achievements to presumably increase their desire to learn [16]. By considering these factors, proper teaching or learning methods are constructed to stimulate students' motivation to learn. In this section, the key findings are discussed in regard with relevant literature and present implications from practice and future research.

A. Scaffolded Confidence

Overall, in the findings, students reported being primarily interested in PjBL. The students found interactive hands-on activities interesting, which aligns with other studies that demonstrate the positive outcomes of project-based learning [32], [33], [34]. However, students' responses in regard with scaffolding in PjBL environments emphasize that proper implementation of scaffolding is essential to enhance student confidence and capturing their attention in the self-directed learning process. From a theoretical standpoint, the concept of scaffolding is best presented in Vygotsky's work on the zone of proximal development (ZPD). In the context of learning and development, the theory describes ZPD as the distance between the learner's capability to achieve tasks without assistance and the learner's capability to achieve them with guidance from a teacher or a skilled person [35]. Scaffolding and the ZPD has become synonymous in the literature which argues that with proper scaffolding, a student would have enough assistance to achieve the task during the ZPD [36].

As the literature notes, the lack of scaffolding may prevent student motivation to learn in the aspects of capturing student's attention [37], [38] and gaining the confidence to succeed [38]. Also, systematic review of literature notes if there is a lack of guidance from the teacher, scaffolding in the form of reference materials may not contribute effectively to the students' learning progress [39]. Furthermore, scaffolding is most effective when the support is linked to the needs of the learner [40]. Therefore, encouraging proper scaffolding in an educational environment where students will receive the assistance needed to reach an academic level of independence is critical for student success.

The presented study finds that scaffolding was important not only for students' confidence but also pivotal in capturing students' attention in learning process. This implies that scaffolding holds a critical role in overall motivation. These findings are in line with other studies that underscore the importance of appropriate scaffolding to guide students during the self-directed learning process. Implementing proper scaffolding in PjBL may result in greater student engagement [41] and performance [42]. As the engineering and CS community continues to develop and implement new modules in school settings, this calls for more research on finding evidence-based scaffolding strategies. Due to the lack of research-based insights on scaffolding, curriculum developers and teachers may devise and use anecdotal techniques which may yield suboptimal results in fostering students' motivation [43], [44]. From a practice perspective, scaffolding is typically used to support current performance that will lead to the development of the student's ability to perform independently, particularly in environments involving ill-structured problems, such as PjBL [45], [46]. Typical scaffolding approaches involve: 1) building off from prior student knowledge; 2) tying to the ongoing observance of students' abilities; and 3) simplifying the task elements in a manner that enables productive struggle amongst students [47]. Therefore, scaffolding is seen as an assistance [35] as well as an interactive support [47] that leverages student's prior knowledge and fosters their meaningful participation and development of skills that will assist them in reaching independent performance. The findings point the ways in which this can be achieved.

1) By including clear directions and instructions such that students are engaged. As suggested in the findings, instructors may first assess students' prior knowledge on programming and math to develop/identify resources for students as they begin to work on assigned task.
2) Students' attention can be consistently captured by tackling repetitiveness, time consumption, and negative struggle amongst students, based on informal observations and formal student feedback.
3) Scaffolding does not necessarily have to be always in the form of instructional material and resources, rather can also provide socio-cognitive support [48], [49], [50]. As noted in the findings, group work and teacher interactions can also be a positive support that increases students' confidence in a classroom.

B. Contextualized Relevance

Based on the findings, the alignment between project content and its contextualization in students' real-life scenarios is an important motivational factor. This resonates with the ongoing issue of limited inclusion of real-world learning experiences in traditional classroom settings [51]. Situated learning is one theoretical work that can be used to forgo the limitations of traditional learning environments and develop learning environments that lead to the inclusion of real-world learning experiences through integration in the curriculum content. Situated learning involves the idea that most of what an individual learns directly relates to the situation in which it is taught [52]. Researchers have reported the positive impact that situated learning in real-world contexts has on student outcomes and motivation [53]. Furthermore, literature underscores that the process of learning best occurs through interventions that combines learning activities with students' contexts and culture [54], [55], [56]. In the study, students found relevance in not simply the real-world contexts, but specifically on how the real-world contexts related to their day-to-day life experiences. Often hypothetical scenarios were created to teach students with real-world contexts. But, if the students are unfamiliar and lack knowledge about the hypothetic real-world context, they are likely to be less motivated. As noted in the findings, several students reported feeling confused and demotivated as they did not identify the relevance or usefulness in the project context. This calls for more targeted contextualization in PjBL by creating scenarios where students can relate the real-world contexts with their day-to-day activities. For example, as detailed in findings, a project asking students to build a chicken feeder sensor might be a more relevant contextualization for a student living in a farming community, than a sensor for guiding movement of a space rover on Mars. By this example, it is reiterated that it might be more effective to use local contexts that are rooted in students' day to day activities, rather than hypothetical scenarios whose understanding is contingent on students' prior knowledge and experiences. Furthermore, since students have more experience in their local day to day contexts, this will help in highlighting their understanding of the situated problems as "assets" that they bring to the learning environment, rather than promulgating the lack of knowledge/exposure to specific topics (e.g., Mars rover) as "deficits" [57], [58], [59]. It is acknowledged that student level contextualization for every student individually may not feasible. Nonetheless, educators may work toward community level contextualization so that the projects related with most of the students' backgrounds. Alternatively, educators may use educational simulations to better situate the project-based learning environments. Researchers have incorporated educational simulations and have received positive results of situated learning in a traditional classroom context [60]. This calls for more research on contextualization in PjBL environments, particularly for engineering and CS education in precollege settings [52].

C. Intrinsic Satisfaction

Motivation is generally categorized into intrinsic or extrinsic motivation [61]. Intrinsic motivation can be defined as the motivation driven by the pure enjoyment of task engagement, which occurs internally within the individual. Conversely, extrinsic motivation is defined as the motivation driven by financial or external compensation, which occurs outside of the individual [62], [63]. Although motivation can fall under either group, from an educational perspective motivation is seen as coherently intrinsic and extrinsic as students need internal and external incentives to learn [64]. Identifying students' internal and external motivational factors provides the necessary tools needed to improve student engagement in learning, as motivation is seen a prerequisite of and a necessary element in student engagement [65]. However, although intrinsic and extrinsic motivation are simultaneously important, out of the two – intrinsic motivation is noted as one of the strongest significant factors that influence student intention to drop out of an engineering education [66], [67], [68].

In coherence with other studies [69], internal satisfaction which constituted intrinsic factors informing students' motivation emerged was widely noted in students' responses in addition to extrinsic factors. In engineering education, intrinsic motivation has been identified as a critical motivational factor that significantly affects a student's decision to enlist in an engineering program [14]. In line with the literature, students who possess intrinsic motivators are most likely to succeed in engineering programs than those with extrinsic motivators only [70]. For example, intrinsic motivators, such as liking math and science, are noted to be more powerful to push a student to finish their coursework, than salary ambitions or perceptions of prestige [70]. Analogously, as the findings suggest, it is important to consider intrinsic factors in PjBL in addition to external factors. More importantly, the findings identify what the intrinsic factors are based on students' responses. Specifically, it was found that in addition to working through a challenging project and understanding a concept, students were intrinsically satisfied when they helped each other in PjBL setting, and when they internalized that they developed certain skillsets that may be beneficial for them in their current and/or future academic trajectories.

These findings also relate with the other psychological theoretical works on motivation. For example, self-determination theory is a widely used theoretical framework which postulates that satisfaction of basic psychological needs, such as autonomy, competence, and relatedness, provides the necessary sustenance for intrinsic motivation [71], [72]. According to the framework, autonomy refers to controlling your own choices and exercising them freely as best seen; competence refers to possessing the knowledge and skills necessary to succeed; and relatedness refers to belongingness and to a sense of community [72]. In the findings, the aspect of helping peers in the learning process is an example of how students demonstrated a sense of community in the learning environment. Similarly, working through a challenging project is an example of how students were able to exercise autonomy in the learning process, and understanding concepts or developing skills to succeed exemplifies with the competence aspect.

In addition, it is noted that these internal factors may not necessarily work in isolation with each other, rather, they may inform one other. For example, students reporting that they felt satisfied when helping others (relatedness), may stem from students' first being able to understand the concepts (competence) by working through a project (autonomy). Therefore, it is argued that student motivations are likely to be intertwined and call for further research on examining the dynamics of student motivation factors as students engage in PjBL environments. Finally, based on the findings, it is not contended that extrinsic factors should not be excluded in lieu of intrinsic factors. Several studies have shown that students are extrinsically motivated to get good grades [4]. Also, researchers have recommended considering different aspects of student motivation in instructional design [73]. Thus, external reward should co-exist to foster student motivation and stimulate their engagement in PjBL in classroom settings.

VI. Conclusion

Motivation has become a critical concept in engineering education and a wide range of studies have been conducted to understand the different theories and definitions that define it. In the context of curricular and instructional design, it is critical to consider students' motivational factors to ensure their effective engagement in the learning process. The ARCS model of motivation is one widely used framework that provides guidance to educators on improving the motivational appeal of instructional materials. In addition to providing support for the comprehensibility and utility of the ARCS model of motivation, the presented study unpacks what the model factors mean from a students' perspective, particularly in regard with PjBL for engineering/CS education. The findings suggest implementing learner-focused scaffolding in PjBL environments to assist students and foster their ability to perform independently on a task, improving the relevance of the classroom content with the real-world context that students have experiences in or are knowledgeable about, and focusing on stimulating intrinsic motivation in addition to extrinsic rewards. Practitioners may use these findings to inform the design, development, and implementation of engineering/CS projects in high school settings. Also, as intended in future work, it is encouraged that educators conduct similar studies as they develop and implement innovative educational approaches to better align with students' motivation.

Furthermore, this study is limited to the sampled participants, but the inclusion of different high school settings improves the usefulness of the findings in similar contexts and settings. Nonetheless, researchers may build on the presented work to conduct large-scale studies that include students from a wide range of demographic, academic, and geographical backgrounds. The findings from such work can also assist in developing specialized focus survey instruments that can compliment existing generic instruments to assess student motivation in learning environments.

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