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Research Article

Motivational design for inclusive digital learning: Women college engineering students' motivation for online STEM learning

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ABSTRACT

This study identifies women college engineering students' perception of online Science, technology, engineering, and mathematics (STEM) learning and factors that influence their learning motivation during the COVID-19 period. By conducting interviews with ten women engineering students and applying attention, relevance, confidence, and satisfaction (ARCS) model, this study aims to answer two questions: (1) How did women college engineering students perceive their experience with online STEM learning during the pandemic? (2) What category/categories based on ARCS motivational design model primarily account for women college engineering students' learning motivation with online STEM learning during the pandemic?

The results show that the online learning format influenced women college engineering students' perception regarding their academic plans, learning styles, learning environments, peer learning, and learning satisfaction. The most influential categories from ARCS model were 'confidence' and 'attention'. Findings suggest that the online STEM learning format influenced women college engineering students' learning motivation. The online format led to (1) low expectations for attention category when analyzed using ARCS model, (2) anticipation of more self-control, and (3) a desire for more peer interactions in their online STEM learning.

As students would have new expectations for the role of online learning due to their experience during the pandemic, assessing women students' emerging motivational needs for STEM online learning is critical in developing a more inclusive instructional system design process in the future.

Keywords: motivation, motivational design, STEM, women engineering, online learning, inclusive design

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) occupations account for more than 6.0% of all jobs in the USA, providing the foundation for the nation's competitiveness in the global arena (United States Census Bureau, 2021; McEntee, 2020). If the boundary of STEM related occupations is widened to include electricians, licensed nurses, military, etc., 67.0% of all jobs in this country and 69.0% of GDP can be directly attributed to STEM professions.

Traditionally however, number of women in the STEM has been low, and while this has improved over the years, still more than 73.0% of all STEM workers are male. In particular, women workforce has not increased in computer and engineering occupations, which serve 80.0% of STEM jobs. Women received only 20.0% of bachelor's degrees in engineering and computer science between 2017 and 2018 academic year (Roy, 2019). To address this issue, efforts to increase women students in STEM fields in the higher education setting are perceived to be an important issue and have been widely studied.

It should be noted that online learning is of critical importance for women college students in STEM as women tend to enroll in higher numbers for online courses compared to their male counterparts, and this is even more pronounced for STEM courses when directly compared to those offered face-to-face (Wladis et al., 2015). Therefore, making online education effective for women college students is an important mission in STEM majors.

Due to the sudden change of instructional delivery modalities mandated by COVID-19 from face-to-face to online settings, students' needs, across educational contexts, required to maintain their motivation in online environments have been revisited and reaffirmed in the literature (Huang, 2013; Means et al., 2020; Park & Choi, 2009; Zaccoletti et al., 2020). In other words, providing sufficient motivational support in online learning environments is essential to engage learners cognitively, socially, and effectively with intended learning activities (Huang, 2013; Kearsley & Shneiderman, 1998) as learners have full autonomy over when and how to initiative or continue intended learning processes (Dhawan, 2020; Keller, 2008). Such motivational support in online learning is complex in nature due to the students' diverse needs. Among women learners in online STEM learning, providing formal and informal learning programs through online learning options could lead to long-term learning outcomes in academic advancement, informed decision-making, and increased participation in STEM fields (Amina, 2021). Online learning in STEM, however, could impact women learners' self-perception as well. In an online biology course, women college students are likely to show lower confidence in their academic performance (Cromley & Kunze, 2021) while ethnically underrepresented students have found less motivation to participate in online STEM learning (Asgari et al., 2021; Cromley & Kunze, 2021; Walsh et al., 2021). These recent findings underscore the importance of students' social culture differences, which influence their learning motivation in online learning environments. To retain women college students in online STEM learning, considering women students' motivational needs in designing the instruction process is critical.

Instructional system design (ISD) is a tool by which principles of learning and instruction can be translated into strategies that account for instructional and evaluation activities, as well as resources. Generally, ISD is different from alternative means of instructional planning in that it calls for a higher requirement for care, precision, and expertise during the initial planning phase (Smith & Ragen, 2005).

Ineffective ISD can bring about a deterioration of motivation and poorly executed activities, leading to long-term negative impacts. The role of ISD in STEM learning has been identified by prior studies. In STEM learning environments, ISD has supported students' self-efficacy (Rockinson-Szapkiw et al., 2022) and learning motivation (Abdool et al., 2017), increased learning outcomes (Maj, 2020; Vojinovic., 2020), changed their attitude toward the STEM field (Hu et al., 2020), and improved problem-solving performance (Wang et al., 2018). Proper ISD must consider a number of complex factors, including motivational factors that can have varying degrees of impact in the implementation and instruction phase. An effective ISD process requires deeper insights and a multi-perspective to overcome learning challenges in different contexts (Hardre, 2005; Seels & Richey, 1994). Especially in higher education settings, this process is involved with reforming curricula, developing programs, and changing system processes. Thus, ISD process requires capabilities to be flexible and adaptive to reflect the connections and collaborations with others (i.e., policies, systems, and faculty expertise and expectation) (Vovides, & Lemus 2019) to not only help learners achieve learning objectives but also to overcome many potential barriers that learners would face during the learning experience.

The study contends that this ISD process should be more inclusive by considering women college students' motivational needs in online STEM learning as motivation plays a significant role in the online learning environment. This is deduced by focusing on the importance of motivational design in ISD by applying attention, relevance, confidence, and satisfaction (ARCS) model (Keller, 1987), which is one of the most frequently used in the literature (Sung & Huang, 2022). ARCS model defines four major motivational conditions, diagnoses learners' motivational needs, and provides a systematic design process.

Purpose of the Study

This study aims to identify emerging patterns that influence women college students' motivational needs in online STEM learning processes and environments. The findings can improve women college students' learning motivation in online STEM learning by informing ISD process.

Research Questions

1. How did women college engineering students perceive their experience with online STEM learning during the pandemic?
2. What category/categories based on ARCS motivational design model primarily account for women college engineering students' learning motivation with online STEM learning during the pandemic?

REVIEW OF LITERATURE

Innovations in responsive online course design strategies continue to evolve at a rapid pace as more than six million college students are expected to be engaging in at least one distance learning program (Yang, 2017). Consequently, the popularity of online STEM learning has also risen to an unprecedented level in higher education settings. This rise in online STEM classes unfortunately has not been adequately accompanied by effective ISD strategies and many of the classes have been operating using antiquated protocols. This is all the more important as we note that online STEM learning can present significant challenges due to more hands-on activities and live demonstrations.

Online STEM Learning for Students From Underrepresented Groups

Efforts to improve the learning outcome of students from underrepresented groups (American Indians or Alaska, Natives Black or African Americans, and Hispanics or Latinos) (National Science Foundation, 2023) in online STEM learning have been investigated. According to previous studies (Angiello, 2002; Halsne & Gatta, 2002; Kaupp, 2012; Salvo et al., 2017; Wladis et al., 2015), underrepresented groups are not enrolling in online courses at the same rate as their counterparts, with even less enthusiasm towards online STEM courses in higher education settings. The lack of underrepresented groups' participation in online STEM classes may be even worse than a similar comparison for in-person classes in STEM (Wladis et al., 2015). Controlling for 'non-traditional' student characteristics, Black and Hispanic students were significantly underrepresented in online STEM courses. This disparity was particularly pronounced for Black and Hispanic male students, followed by Hispanic women students (Wladis et al., 2015).

Although historically Black colleges and universities (HBCUs) have actively advocated for their students to pursue STEM education through online courses as a means of taking advantage of increasing opportunities in STEM careers (Museus et al., 2011), data show that Black students still significantly trail their white colleagues in registering for distant learning courses. (Waits & Lewis, 2003; Salvo et al., 2017) This disparity between the two student groups is more pronounced in STEM when compared to other fields including social sciences, business, and education at HBCUs (Flowers et al., 2012). It is even more of an issue when we consider that students from underrepresented groups are now more likely to be deprived of the online learning skills that are becoming more essential to potential employers. These valuable technical skills are becoming the foundation for much of the training in new workplaces and lack of familiarity can be a significant disadvantage (Mossberger et al., 2007).

Women Students' Online STEM Learning

Women are also underrepresented in STEM undergraduate programs (Chee, 2005; Conway, 2009; National Center for Education, 2022). While the number of women who receive STEM degrees in higher education has increased, still only 32.4% of all STEM degrees went to women and 20.0% of bachelor's degrees in engineering and computer science were received by women during the 2017 and 2018 academic year (USAFACTS, 2020; Roy, 2019). Not many women voluntarily chose STEM disciplines (St. Rose, 2010) for their education and career. As more than 75.0% of the fastest-growing high-paying jobs in the future are expected to require a strong STEM education (Hackling et al., 2014; Simon et al., 2017), it is more important than ever that we encourage and support women to enter STEM.

Contexts facing women college students' online STEM learning can also be understood through gender differences. According to Yoo and Huang (2013), in the higher education setting, women students have significantly stronger intrinsic motivation for online courses. Also, it should be noted that unlike the aforementioned racial patterns, women tend to enroll in online courses at a higher rate compared to their male counterparts (Wladis et al., 2015). In massive open online courses (MOOCs) environment, while women adult learners are less likely to enroll in STEM-designated degree programs than their male counterparts (Jiang et al., 2018), their completion rate is almost equal to male registrants. Decreasing gender gaps for MOOC STEM program enrollment and course completion rates were shown in less gender-equal and less economically developed countries. These findings suggest that online STEM education could be an important entry point for women to start academic training in STEM by increasing rates of STEM degree completion among women students (Wladis et al., 2015).

Online STEM Learning During the Pandemic

According to the survey in 2020 involving 896 STEM faculty in higher education (22.0% biological science, 18.0% engineering, 18.0% physical science, 17.0% computer science, 14.0% mathematics and statistics, and 12.0% other majors), 73.0% of them changed their courses to be online at the outbreak of the pandemic (Seaman et al., 2021). Brunelli and Macirella (2021) reported that the main challenges during this time were providing practical hands-on activities, and that online teaching could not merely be a transposition of face-to-face lessons in a virtual context without timely preparation.

Cromely and Kunze (2021) argued that students faced different challenges based on their gender, race, and socioeconomic status using a biology course, which went online during the pandemic. For example, ethnically underrepresented students were generally less motivated by 'mastery goal orientation' (construing the aim of learning as a deep understanding of the content). Motivation for first-generation students was more likely to be correlated to variables such as 'interests' but less so with 'autonomy', 'self-efficacy', and 'performance-avoidance goal orientation (my goal is to avoid performing poorly compared to others)'. The same study also reported women college students' challenges with online STEM learning during the pandemic. Women students, in general, were more likely to exhibit a decrease in 'self-concept' (i.e., academic self-concept: seeing oneself as good at a topic), and even more significantly in 'self-efficacy (i.e., feeling confident that one can perform subject-specific tasks required in a learning situation)'. Studies during the pandemic suggest that students' motivation status differs according to their social-cultural backgrounds and their current context (Amina, 2021; Asgari et al., 2021; Cromley & Kunze, 2021; Walsh et al., 2021).

Motivational Design in Instructional System Design for STEM

The definition of motivational design in this study is from Keller (2010). Motivational design in the context of teaching specifically refers to 'strategies, principles, processes, and tactics for stimulating and sustaining the goal-oriented behaviors of learners. The aspects considered by motivational design theories are connected to what ISD deals with within the learning environment. Therefore, motivational design can add another element to ISD (Hess, 2015). Motivational design theory supplements ISD theory by letting learners acquire and retain knowledge. Also, effectively designed instruction increases success rates, which influence learners' motivation (Visser & Keller, 1990). It should be noted that motivational design is only meaningful when understood from a synergistic perspective encompassing other factors such as the environment and the curriculum itself. For motivational design to be effective, instructional goals have to be supported by motivational design tactics (Keller, 2010).

There is no single motivational design principle that works for every situation as human motivation is strongly impacted by individual experiences, personal characters, and their unique environments (Keller, 2000, 2010). Also, experimentally sound strategies are only valid within the research environment and must be adjusted according to the application setting (Keller, 2010). Therefore, the goal is not to identify a singular optimal motivational strategy but to devise a systematic audience analysis, which takes into consideration previous knowledge regarding primary characteristics of human motivation with a focus on identifying which factors influence this motivation to be enhanced or diminished. In so doing, we can identify and design strategies that can lead to enhanced motivation by the learners for a given situation.

Table 1. Four categories & subcategories of ARCS model (adopted from Keller, 2000, p. 4, 2010, p. 45)

Categories definition	Subcategories	Process questions
Attention: Capturing interest of learners: Simulating curiosity to learn	• Capture interest (perceptual arousal) • Simulate inquiry (inquiry arousal) • Maintain attention (variability)	How can I make this learning experience stimulating & interesting?
Relevance: Meeting personal needs/goals of learner to affect a positive attitude	• Relate to goals (goal orientation) • Match interests (motive matching) • Tie to experience (familiarity)	In what ways will this learning experience be valuable for my students?
Confidence: Helping learners believe/feel that they will succeed & control their success	• Success expectations (learning requirements) • Success opportunities (learning activities) • Personal responsibility (success attributions)	How can I via instruction help students succeed & allow them to control their success?
Satisfaction: Reinforcing accomplishment with rewards (internal & external)	• Intrinsic satisfaction (self-reinforcement) • Rewarding outcomes (extrinsic rewards) • Fair treatment (equity)	What can I do to help students feel good about their experience & desire to continue learning?

Motivational design strategies also have been applied to ISD for STEM education. Abdool et al. (2017) applied a role-playing game and pop-culture references to motivate students to learn database system design and as a result, this design increased students' interests and learning outcomes. Subramanian and Budhrani (2020) also showed the effectiveness of the project-based learning model for the online computer science course on students' self-regulation and interests by motivating students and providing engaging learning environments.

ARCS motivational model

ARCS model (Keller, 1987), as a prescriptive design theory, is well established and has been continuously developed over the years for a variety of different learning situations to identify key influences on the learners' motivational needs. ARCS model articulates concepts and variables that characterize motivational factors in learning and subsequently deploys means to enhance the motivational appeal in the instruction process. ARCS model is composed of four major motivational conditions: attention, relevance, confidence, and satisfaction (**Table 1**). These conditions must be accommodated for motivation to be enhanced in the learning process. Based on this premise, ARCS model lays out a systematic motivational design process composed of 'define, develop, design, and evaluate', which can be integrated with conventional ISD and development models (Huang, 2013; Keller, 1987, 2010). Unlike other representative ISD models (e.g., Dick and Carey and R2D2 model), ARCS model design process is more a problem-solving process than being prescriptive/linear as most situations do not lend themselves to a prescribed set of solutions and strategies (Dick 1996; Okey & Santiago, 1991: Wills, 1995, 2000). Specific situations have to be carefully analyzed before a strategy can be optimized. Therefore, an 'analyze audience steps' process is emphasized in ARCS model.

Studies grounded in ARCS model have used it to design and evaluate new instructional tools or to assess existing educational tools with a focus on learner's motivation status based on these four categories (Sung & Huang, 2022). For STEM education, Arora and Sharma (2020) indicated two case study results that showed how applying ARCS model to design instruction for the 'environmental science and engineering' and 'water and wastewater engineering' courses influenced students to have better learning outcomes. Another study (Li &Ma, 2021) implied that for the statistics course, the blended learning format was found to be the most motivational format for learners in terms of attention, confidence, and satisfaction. By applying ARCS model, this study addressed that the blended learning format provided students with more guided instructions, peer support opportunities, and flexibility than in-person or online formats.

ARCS model design approach has been rigorously studied for diverse learners and learning environments, but there is a notable lack of studies, which show learners' motivational differences based on social and cultural backgrounds. There is one study (Cintron et al., 2019) that applied ARCS model to identify diverse learners' different motivational needs based on their social and cultural backgrounds. Using a large introductory computer science class (in-person format) with students from diverse backgrounds (e.g., gender, race/ethnicity), this study showed that 'underrepresented minority (URM)' students perceived less instructor support and less collaborative work than their peers in majority population groups). The differences between URM students and non-URM students suggested the need for a more inclusive learning environment to engage with diverse learner populations in STEM education.

Li and Keller (2018) suggested that ARCS model needs an extensive empirical foundation in computer-based and/or solely online learning environments and the long-term impacts of this model should be further studied. Through ARCS model, this study sought to identify emerging context-based categories, which influence women college students' motivational needs based on the online STEM learning contexts.

METHOD

Research Design

A qualitative research design was employed by conducting interviews with participants. Qualitative research should be established on the framework of identifying processes that connect people, events, and their situations by articulating how some events and situations impact others through an inductive approach while highlighting particular situations and people, with an emphasis on description (Maxwell, 2008, 2011). Qualitative research design was chosen since it would enhance the understanding of the social and cultural context in which the women college engineering students were situated for their online STEM learning experience during the pandemic. In addition, this research design answers how the context influences their learning motivation and would be able to identify unanticipated emerging patterns based on participants' experiences.

Research Setting

This study was conducted within college of engineering at a public research-one university in the Midwestern USA. This college of engineering offers nationally recognized STEM degree programs. Its mission not only includes delivering excellence and innovation in engineering education but also increasing the diversity of faculty and students by building a diverse pool of students, faculty, and researchers. College of engineering is chosen for two reasons. First, it provides access to students taking the same course but from different STEM majors. Second, engineering courses at this university for undergraduate students were rarely delivered fully online before the pandemic. This study's focus on women college students' online STEM learning experience during the pandemic provides a valuable opportunity to observe unexpected issues arising from the lack of experience in delivering fully online learning to undergraduate engineering students.

Sample

A total of ten women college engineering students participated in a one-on-one virtual (via Zoom) interview between February and March of 2022. These participants took the same online course (field of energy science) in the Fall 2020 semester, which was a required course for several engineering departments. This course was selected as the sampling frame because it is typically delivered to a large number of students from all engineering majors with basic mathematics and physics backgrounds. In Fall 2020 there were 120 students, including 16 women students (who identified themselves as 'women' on the course registration). Prior to the pandemic, these lecture-focused classes were held for one hour per class and three times a week, followed by office hours. During COVID-19 (i.e., Fall 2020) the course lectures were delivered online through Zoom three times a week. The chat function was blocked by the instructor's request to help students focus on the lecture. All lectures were delivered synchronously, and the recording was posted online as references. All lecture materials, homework, and homework solutions were also posted online. Two graduate teaching assistants were assigned to the course to help students with questions. The students were evaluated through weekly homework, two quizzes during the semester, a midterm exam, and a final exam.

The participants' majors included mechanical engineering, system engineering, nuclear engineering, aerospace engineering, civil engineering, and agriculture and biological engineering. When participants took this online course in Fall 2020, six of them were in their second year, one of them was in her third year, and two participants were in their fourth year as undergraduates. The year of one participant is unknown. Seven of them had no online learning experience prior to Fall 2020; one participant had some online learning experience with courses for their major (not due to the pandemic); one participant had some experience only with elective courses. Participants with some online learning experience prior to the pandemic reported that they chose the online format because of its convenience. All participants reported that their courses were replaced with the online format abruptly in March 2020 during the semester due to the pandemic. Participants also mentioned that in the Fall 2020 semester, all courses (including this course) were offered in an online format. Our participants described that four of them were living on campus during this semester while others said that they were at their homes or other locations in different time zones.

Instrumentation

Semi-structured interviews were applied for data collection (Maxwell, 2012). Interview questions were developed based on ARCS motivational design model. Interview questions included six open-ended questions, which addressed students' attention, relevance, confidence, satisfaction, suggestions, and other additional thoughts regarding this course. See **Appendix A** for the interview questions.

Data collection

Interviews were conducted between February and March 2022 by following the finalized interview protocols and questions. All interview data collection protocols were reviewed by the Office for the Protection of Research Subject at the university level. Data collection was carried out, as follows. With assistance from the class instructor, recruitment emails were sent to all women students (n=16) in the given class. The goals of this study, consent information, and participation duration were sent with the recruitment email. Ten women students voluntarily participated in the interviews, resulting in a 62.5% response rate among women students in the class. They were invited to the 60-minute individual virtual interview (via Zoom due to restrictions for the pandemic at that time) with the researcher. Only audio was recorded for all interviews following the participants' agreements for data analysis purposes.

Data analysis

The entire data analysis process was conducted by two researchers to increase internal reliability (Anfara, 2002). After two researchers worked through half of the data independently, the inter-coder reliability test was conducted (MacPhail et al., 2016). Researchers chose two interview transcripts and Cohen's kappa values were one and 0.85, which is considered a perfect agreement between the two researchers.

Prior to the analysis, all interview data was transcribed by the researchers and was reviewed with interviewees to check for accuracy. Once the transcription accuracy was verified, the data was analyzed using the 'directed content analysis process (Assarroudi et al., 2018; Hsieh & Shannon, 2005; Kaldheim et al., 2021; Kibiswa, 2019)'. The purpose of direct content analysis in qualitative research is to validate or expand existing theories. Thus, existing theories and prior studies can be used as initial coding schemes. For this study, each interview transcript was coded based on the theoretical background and categorization matrix of ARCS motivational design model (Keller, 2000, p. 4). ARCS model identified emerging patterns as categories (attention, relevance, confidence, and satisfaction) and their subcategories. For this process, an extra column was added to code the important factors, which were not related to ARCS model categories but still influenced participants' learning motivation. In addition, the overall patterns of all interviewees' were identified to answer research question #1.

FINDINGS

How Did Women College Engineering Students Perceive Their Experience With Online STEM Learning During the Pandemic?

Theme 1: Impact of online format on participants' academic plans

While students did have mixed feelings about taking such a major course in an online format, none of them postponed or changed their academic plans due to the delivery format of this course. There were some participants who expressed their concerns before the course started due to the delivery format. However, six participants reported that they had to take this course because it was required for moving to the next level of courses. Participants' thoughts regarding taking online courses for their major course include:

> "If I did not take it at that particular time, I'd be behind, at least with my respect to my course plan. And I think I was just understood that it kind of had to be offered online just due to COVID-19

regulations and things like that. So, I was like, this is kind of unfortunate, but I was not really anxious or anything like that …"

"I was concerned because it's like one of the first courses of mechanical engineering that is like one of the core courses and having it be online there is less like, I guess, help that is offered."

Theme 2: Impact of online format on learning styles & learning environments

Eight participants addressed that taking online courses helped them manage their time schedule effectively by saving time between classes. When they were taking this course, students had motives and expectations that they could have more flexibility and use time at their own pace due to its delivery format. Also, this format provided a physical convenience for them to attend more supplementary sessions (e.g., TA sessions, office hours) that they may not have been able to attend had it been completed in person. Participants' quotes regarding the benefits of taking a course in an online format include:

"I'd say, like in getting people to go to things like higher attendance online is better …"

"… I was like in a comfortable environment [while taking this course], and I kind of had a little more control over my own schedule and what I could be doing before, after and during class."

Theme 3: Effect of online format on peer learning

Most participants pointed out that there is a lack of formal/informal peer interactions in the online format. As the online course format limits interactions among students during and after class, students who do not have existing friends could experience isolation in the learning process. Even if students were satisfied that they were able to have sufficient time for questions during class, office hours, and TA sessions, they would have liked more opportunities to learn from other classmates' opinions by having sufficient interactive discussions. Participants also pointed out that the online format allowed them to have very limited methods to share their thoughts and questions through the screen not only with other classmates but also with the instructor. Participants' quotes regarding suggestions for this course include:

"I would say I'd like a discussion element to it because it's a course, where you definitely need to have people to work on the homework with or alongside to kind of borrow from each other. And with pretty much just the lecture and like a little bit of the help sessions that was not as present, like a mandated discussion going further into problems, I think would be extremely helpful."

Theme 4: Impact of online format on satisfaction

Participants stated that the consistency of learning requirements and assessment methods increased participants' satisfaction with their learning outcomes and final grades after the semester even with students' concerns about the new delivery format. The instructor emphasized that the shifting format would not impact students' grades and learning methods by supporting them with additional Q&A and TA sessions. The instructors' clear declaration about the learning goals and course expectations by acknowledging the changes in the delivery format increased satisfaction in the students.

Also, some participants pointed out how implementing fair treatment to assessment methods increased their satisfaction, especially in an online format. Some participants showed their concerns regarding taking exams in a fair way in an online format and they expressed that the instructor's clear responses to those problems were much needed for them to be satisfied with their learning outcomes. In this course, there were students' reports of some students sharing their answers with others during the final exam. Participants said that the instructor's transparent and fair treatment of this problem made them feel assured about their exam results.

Participants' quotes regarding fair treatment include:

"… The way the course is structured and the way that our professor delivered the material. It did not really leave room to struggle as long as you going to class and getting clarification on anything he needed from the professor."

What Category/Categories Based on ARCS Motivational Design Model Primarily Account for Women College Engineering Students' Learning Motivation With Online STEM Learning During the Pandemic?

To answer this question, the participant's responses were classified by each category and its subcategories (Keller, 2010, p. 92, p. 126, p. 159, p. 189) (**Table 2**).

Most influential categories for engineering college women students' motivation for this course were 'confidence' & 'attention'

'Confidence' was mentioned the most (46.0% out of all coded dimensions) by interview participants than other categories (e.g., attention, relevance, and satisfaction). Participants pointed out that instructor's efforts to provide enough time to answer students' questions, repetitive reviews to facilitate solid understanding, and additional TA sessions for questions and reviews helped them to experience various perspectives on the topic. This experience made them feel confident about successful learning outcomes (**Table 2**). Also, by reviewing recorded lectures and uploaded homework solutions, participants were able to have personal control opportunities. These opportunities gave them confidence to catch up on content at their own pace through individual efforts as needed (**Table 2**). Besides, as participants did not have much experience with online learning, they were concerned at the beginning of the course. But instructor's clear statement regarding learning goals and assessment criteria was stated as factor, which affected their confidence. They were able to understand course requirements clearly and reduce their concerns about new delivery format.

In a different sense, 'attention' is one of the categories, which influenced women college engineering students' motivation the most. Participants showed low expectations on the 'attention' aspect of this course as the fact that the course was online did not attract their attention or was perceived as helping with their learning while they were signing up for the course. Participants had this pre-assumption because of their experience with the previous semester (Spring 2020 semester, unexpected change to online format due to the pandemic) and their perceptions of distractions caused by using computers for classes. One of the participants also pointed out the special situation of the quarantine as the main reason for not being able to muster enough attention to this course and or learning itself.

The subcategory, which positively affected participants' motivation under 'attention' is 'variability'. Variability is about retaining students' attention by providing diverse styles of presentation methods and applying practical analogies with students' interests and introducing unexpected circumstances (Keller, 2010, p. 92). In this course, using the interactive note-taking method worked to catch some of the participants' attention. These participants described that instead of looking at already written notes (or slides) through a screen, instructor's real-time note writing and solving problems improved their concentration during the class and even aided them to remember better what they learned.

Nature of 'relevance' & 'satisfaction'

In terms of 'relevance', participants' strong desire to achieve their goals of adhering to their academic plan was identified as the most significant factor. It strongly made them take this course regardless of the delivery format, but also negatively influenced their motivation. As a result, most of the participants showed low interest in considering the values and goals of taking this course beforehand. During the interview, only a few of them linked their career goals and academic goals to the content of this course.

The other subcategory identified due to delivery format of this course is participants' motives and expectations of having more flexible study time at their own pace (**Table 2**; 'match interest'). They expected that online courses would allow them to use time flexibly and accomplish other tasks (e.g., job interviews, work, and other courses) simultaneously. Participants' motivation through 'satisfaction' with this course is closely related to their 'intrinsic reinforcement'. Starting with low expectations and interests, participants indicated that they were very satisfied with their learning outcomes. They realized that they actually learned a lot about this topic and were able to increase their critical thinking skills and understand how to apply this topic to the next level course more effectively. Also, in terms of extrinsic rewards, all of them were satisfied with their final grades. Two respondents reported that their final grades were higher than they expected, which compensated them for this difficult period.

Table 2. Participants' responses based on ARCS model

ARCS	Subcategory	Quote examples
Attention	Capture interest (perceptual arousal)	"Professor utilizes Zoom, but they also utilize other tools outside of Zoom to make sure that we were having as close of an experience to in-person learning as possible... So that kind of helped ease nerves that I was like in a comfortable environment."
	Stimulate inquiry (inquiry arousal)	"[This course] was first class that we actually started to apply principles that we were learning to real life machines that like, relate to my major like engines."
	Maintain attention (variability)	"There are notes that were using like kind of like a PDF & writing on it & sharing his screen at the same time." "Instructor started using online that are synchronous, that they're taking it so that instructor is speaking. And, you know, there's interactions between students & instructor for that specific for course instructor was using a pad."
Relevance	Relate to goals (goal orientation)	"I guess reason I took it was just because it's like my major course, & if I did not take it at that particular time, I'd be behind, at least with my respect to my course plan." "Very important to understanding & learning about that & getting into a career related to that."
	Match interests (motive matching)	"... used to have to balance out classes that were more that took more of my time ... like labs & having to go in person specifically. So, online structure ... really helped balance out my other classes, where I needed to go to a bunch of different places..." "I actually got to use more critical thinking skills & actually think about like how I need to apply equations & for what specific scenarios."
	Tie to experience (familiarity)	"I was already relatively comfortable with. So then I figured that course would be pretty straightforward because it probably would not be a ton of newer stuff that I learned."
Confidence	Success expectations (learning requirements)	"[Instructor's] only goal is to make sure that this transition to online learning would not impact, impact our grades, or impact way we learned. I mean, this course, the instructor really had a strict emphasis of wanting to make this flow that makes this online format flow as easily as possible."
	Success opportunities (learning activities)	"[Instructor] would go over fundamentals, he'd go over practice questions, homework questions, & then he would leave a lot of time in Zoom to answer questions & questions he would answer taking lots of time & making sure he was saving a lot of time during our Zoom classes to go through those questions & problems." "[Instructor] he really was able to answer a lot of questions, & examples he provided was very easy to understand." "TA would come, explain each week's homework, & I thought that was really helpful."
	Personal responsibility (success attributions)	"Lectures were recorded so you can go back & review them if you needed to ... I'd use those a lot for like studying & just knowing the material." "I would try to at least check my homework & see if I'd gotten correct answers before then & after." "There were instances, where I could not make it to class & because lecture was recorded, it was really easy for me to go back on my own time & watch those recorded lectures & make sure I do not fall behind." "It's a little bit easier of to explain it to you, especially if you feel like you cannot ask questions in a larger class."
Satisfaction	Intrinsic satisfaction (self-reinforcement)	"Towards end of semester, I realized that I actually did understand material pretty well, & I had a pretty good grasp on it, which I was kind of scared for." "I actually became really interested in material. And I really. I do not say this for a lot of professors, but I really did enjoy how class was taught & like how instructor just kind of went along & taught class made me kind of interested in something that I did not have to be interested in." "I think I still like I've retained a bit of information from that class, which is more than I could say about a lot of other engineering classes I took."
	Rewarding outcomes (extrinsic rewards)	"I'm satisfied with my homework grades & my final grades."
	Fair treatment (equity)	"Everything that was taught in class & mentioned in reviews by professor, as long as you understood that that is exactly what was on midterms & finals."

DISCUSSION & IMPLICATIONS

The findings from this study suggest three points that we could consider regarding women college engineering students' motivation with online STEM learning.

First, findings proposed that students' expectations regarding 'attention' to online learning within a given context deserve to be assessed before designing an online class. The participants had very low expectations that the online format would get their attention at the outset and this assumption significantly influenced their motivation from the beginning. However, this notion is not based on their 'perceptual arousal', 'inquiry arousal', or 'variability' (**Table 2**). It is based on either their prior experience or (mainly) based on their general perceptions of online learning. Also, this perception will change as students return from mandatory online learning caused by the pandemic to optional online learning setting. Therefore, students' notion of 'attention' needs to be reviewed each time and appropriate solutions should be provided to adjust their 'attention' needs prior to designing online courses as needed. One of the recent studies (Reginaldo & Ching, 2021) measured engineering college students' expectations of online courses between 2020 and 2021 academic year in the Philippines. While this study did not particularly measure students' expectations for their 'attention' matters, it suggested that the findings infer students' expectations based on their online learning experience during the pandemic will practically be applied to the future online course designing process and school policies due to its unique context. As students' perceptions and expectations about online learning would be very different from those from pre-pandemic, their new perceptions should be priorly measured and assessed.

Second, some influential subcategories, which influenced women students' learning motivation were related to the online format itself. For example, for interview participants, 'fair treatment' (**Table 2**; under 'satisfaction') meant not only the consistency between course expectations and assessment criteria but also other factors such as preventing possible disadvantages that may occur to students during exams due to the online format. Participants believed that fair treatment for the exams would reduce students' concerns, which are caused due to insufficient experience with novel unfamiliar assessment methods. Students' concerns about assessment methods in an online format have been discussed earlier in other studies. Chen et al. (2018) investigated the impacts of design elements on college STEM online learning. They pointed out that students' perception of the efficacy of assessment design is closely related to the student's learning satisfaction in online STEM learning.

In another example, one of the participants' personal 'interests' (**Table 2**; under 'relevance') appeared as a result of the online format. Participants expected flexible time management and extra self-control areas when taking this course because it was offered via an online format. In a similar vein, one study (Li & Moore, 2018) reported the unique aspect of the 'relevance' category in MOOCs format. This study suggested that the format of MOOCs is designed for a wide range of different learner groups who have substantially diverse 'relevance' factors. Therefore, various types of assignments would help increase the 'relevance' factor for learners by finding their own relevant connections. These findings proposed that different delivery format brings unique aspects to be considered to motivate students.

Finally, findings revealed that more tools and activities for peer interactions should be designed to increase women students' confidence in the online STEM learning environment. According to participants, online format significantly restricts formal and informal interactions between classmates during and after classes, which influenced their learning motivation, particularly in 'confidence'. They would like to learn from others' thoughts and opinions and make sure they are in the same phase as other classmates to feel more confident about the learning process. As 'confidence' was identified as the most influential and effective factor for them, increasing peer interaction opportunities is a vital consideration for women students. Peer interactions were emphasized in other studies. Hilts et al. (2018) addressed importance of encouraging classmate interaction activities to sustain 'underrepresented students' in STEM higher education settings. Peer interactions provide values and relatedness feelings, which are important methods for students to have competence.

CONCLUSIONS

Findings show that the online STEM learning format influenced women college engineering students' learning motivation. This format led to (1) low expectations for the attention category when analyzed using ARCS model, (2) anticipation of more self-control, and (3) a desire for more peer interactions in their STEM learning. As students would have new expectations for the roles of online learning due to the pandemic experience, assessing women students' emerging motivational needs for STEM online learning is suggested for a more inclusive ISD process in the future.

Limitations

The limitations of this study are twofold. First, since this study was conducted a year after their experience with a full class with online learning, the participants' perceptions regarding online STEM learning may have changed from when they were taking the course. The fact that online courses have now become more routine may bring forth differences in their recollection of their experience, which would have been more novel at the time. Second, in spite of the fact that all the participants are women and have similar majors, other variables of this group influenced their perceptions of online learning, and these variables might have been more diverse and latent due to the pandemic (e.g., students' own perception of the pandemic, family issues, health status, and economic status). These possible variables were not able to be captured in depth in this one-time interview.

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APPENDIX A: INTERVIEW QUESTIONS

1. In what areas and to what extent did this online course (in the 2020 Fall semester) capture your attention?
2. In what areas and to what extent did this online course (in the 2020 Fall semester) relate to your academic interests/learning goals/experience?
3. In what areas and to what extent did you believe that you could be successful in this online course (in the 2020 Fall semester)?
4. In what areas and to what extent were you satisfied with the outcomes of this online course (in the 2020 Fall semester)?
5. If this course is continuously delivered in an online format, how could this course be improved?
6. Do you have any additional thoughts that you would like to share regarding your experience with this online course?