ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37742

Relationship between Course Engagement and Educational Application Engagement in the Context of First-year Engineering Students

Saira Anwar (Texas & M, Department of Multidisciplinary Engineering)

Saira Anwar is an Assistant Professor at the Department of Multidisciplinary Engineering, Texas A&M University, College Station. She received her Ph.D. in Engineering Education from the School of Engineering Education, Purdue University, USA. She earned her M.S. in Computer Science with a software engineering concentration from the National University of Computer and Emerging Sciences, Pakistan. Dr. Anwar also holds an M.Sc in Computer Science from Punjab University College of Information Technology, Pakistan. Dr. Anwar is passionate about research and teaching, specifically translating research into evidence-based teaching practices. For her research, she is particularly interested in designing interventions that help develop students' understanding of conceptually hard concepts in STEM courses. She was awarded the 2020 outstanding researcher award by the School of Engineering Education, Purdue University. Also, she is the recipient of Apprentice Faculty Grant Award, 2022 by ERM division, ASEE. Dr. Anwar has over 13 years of teaching experience, including the University of Florida (Department of Engineering Education), Forman Christian College University (Department of Computer Science), and many other higher education institutes in Pakistan. She taught engineering education, computer science, and software engineering courses. She believes in implementing engaging, motivating, and interactive learning experiences through curricular innovation. She was awarded outstanding teacher awards in 2013 and 2006 by her then employers. Also, she was the recipient of the "President of Pakistan Merit and Talent Scholarship" for her undergraduate studies.

Ahmed Ashraf Butt

Ahmed Ashraf Butt is a doctoral candidate in the school of engineering education at Purdue University with a multidisciplinary research focus that combines theory and practice in the area of learning science, Human-computer interaction (HCI), and engineering education. His primary research focuses on designing and developing educational technologies that can facilitate different aspects (e.g., engagement) of the students' learning and provide an engaging experience. Further, he is interested in designing instructional interventions and exploring their relationship with different aspects of first-year engineering (FYE) students' learning (e.g., motivation and learning strategies). Before Purdue University, he worked as a lecturer for two years at the University of Lahore, Pakistan. Additionally, he has been associated with the software industry in various capacities, from developer to consultant.

Muhsin Menekse (Associate Professor) (Purdue University at West Lafayette (COE))

Muhsin Menekse is an Associate Professor at Purdue University with a joint appointment in the School of Engineering Education and the Department of Curriculum & Instruction. Dr. Menekse's primary research focuses on exploring K-16 students' engagement and learning of engineering and science concepts by creating innovative instructional resources and conducting interdisciplinary quasi-experimental research studies in and out of classroom environments. Dr. Menekse is the recipient of the 2014 William Elgin Wickenden Award by the American Society for Engineering Education. He is also selected as an NSF SIARM fellow for the advanced research methods for STEM education research. Dr. Menekse received four Seed-for-Success Awards (in 2017, 2018, 2019, and 2021) from Purdue University's Excellence in Research Awards programs in recognition of obtaining four external grants of $1 million or more during each year. His research has been generously funded by grants from the Institute of Education Sciences (IES), the U.S. Department of Defense (DoD), Purdue Research Foundation (PRF), and the National Science Foundation (NSF).

Relationship between Course Engagement and Educational Application Engagement in the Context of First-year Engineering Students

Abstract

This complete research paper emphasizes the importance of students' engagement from two perspectives. These perspectives vary based on students' interaction with learning activities or content and their interaction with the educational applications introduced in the class. This paper examines the relationship between these two engagement perspectives, i.e., students' engineering course engagement (Course_Eng) and students' application engagement (App_Eng) in a mobile technology-mediated learning environment. A CourseMIRROR mobile application was introduced in the first-year engineering (FYE) course, which prompted students to write their reflection on lectures' confusing or interesting points after each class. To collect the data on students' course engagement, we administered a validated survey at the beginning and the end of the semester (pre-post manner). Students self-reported their course engagement on four dimensions of engagement: behavioral, social, cognitive, and emotional. We calculated the number of times students submitted their reflections for the app engagement in a semester. One hundred and twenty students from a required first-year engineering course participated in this study by self-reporting their course engagement and interaction with the application. We hypothesize and explore whether students' course engagement has a relationship with their app engagement or not. We analyzed the data using Pearson product-moment correlation to understand the relationships between pre-course engagement, post-course engagement, and app engagement. Furthermore, we conducted linear regressions to understand the relationship between 1) course and application engagement and 2) changes in students' course engagement and app engagement. The study results indicate that students' pre-behavioral and pre-cognitive engagement significantly correlate with students' app engagement. Also, the study highlights the insignificant relationship of students' social engagement, emotional engagement, and app engagement posts using the application. Further, both students' pre-behavior and pre-cognitive engagement are predictors of students' app engagement, while changes in students' cognitive engagement (from pre to post) also significantly predict students' app engagement. We discuss these results in light of implications, limitations, and future directions.

Keywords: first-year engineering education, application engagement, behavioral engagement, social engagement, emotional engagement, and cognitive engagement.

Introduction

Students' engagement is considered a fundamental motivational construct in engineering education and is often associated with learning and experience [1], [2], [3]. Existing literature has defined students' engagement differently depending on the context of its use, where most researchers have discussed engagement with an explicit link to students' academic activities and tasks [4]. For example, in one of the early seminal papers, Meece and colleagues [5] defined engagement as students' participation with the learning material, activities, and community. However, other studies have defined it within the context of the learning environment, where engagement is referred to as students' interactions or involvement in tasks related to the specific learning environment-based tasks [6]. For example, O'Brien and colleagues [7] defined

engagement in the context of a technology-mediated environment (settings in which computer-based applications and simulations are used to support participants' involvement). They suggested engagement as interaction with the technology application(s) and systems in a meaningful way, within a context that may not necessarily be educational in nature. The vital caveat in both definitions was associated with one common principle: "meaningful interaction" with the elements of the contextual environment.

In this research paper, we are using the contextual variations as a premise to define two forms of students' engagement 1) Course Engagement (Course_Eng) describing students' engagement with an engineering course, and 2) Educational Application Engagement (EdApp_Eng) describing students' engagement with the educational application, used in the same course. In the light of existing literature, we define students' course engagement as a multidimensional construct that captures students' behavioral, emotional, cognitive, and social components while studying and interacting with course materials and community [8], [9]. Additionally, we define educational application engagement with students' usage and interaction with an educational application in a meaningful way (i.e., completing the tasks of the application) [6], [7]. We hypothesize that as both course engagement and educational application engagement are based on the principle of meaningful interaction within a broader context of the course (or set of courses), they may have a relationship with one another. Considering this hypothesis in this research paper, we specifically explore the relationship between two forms of engagement in the context of the first-year engineering (FYE) course. The FYE is chosen as the context as it gives a unique perspective of students new to the engineering discipline who are finding ways to stay engaged and persist in the program [10].
More specifically, we explore this relationship by answering two research questions:

1) Do students with high course engagement shows higher app engagement?
2) To what degree do students' app engagement relate to changes in their course engagement?

Theoretical framework and Literature review

We framed this study on two fundamental frameworks: self-system motivation theory [11] and engagement theory [6].
The self-system motivation theory describes engagement as an individual's interaction with the context and associated contextual characteristics [11]. These interactions in a learning context are with learning activities, resulting in different overt and covert qualities of students' behaviors [12]. Drawing from the self-system motivation theory principles, researchers have defined engagement as a multifaceted, multidimensional construct with four distinct yet interrelated dimensions: behavioral, emotional, cognitive, and social engagement [13].

Prior studies define these four dimensions in educational settings [13], [14]. Behavioral engagement is described with overt properties of students' academic participation in the course and class activities with positive behaviors [8]. Studies have used various behavioral characteristics to measure behavioral engagement, which includes the students' number of courses taken, course grades, credits earned, GPA, attitude towards degree major and career, homework completion rates, attendance in class, and participation in extracurricular activities [4], [14]. Emotional engagement includes the positive overt and covert emotional reactions in

response to course work, discussion, and learning material. These emotional reactions can be towards teachers, peers, or course content showing the interest or disinterest, enjoyment or frustration, anxiety or joy for the perceived value of learning [15]. Literature suggests that positive reactions can be induced in students by valuing students' participation and fostering an interactive social culture in the class [4]. Cognitive engagement can be defined with two components of students' behaviors, which are:1) use of learning strategies that promote deeper understanding, and 2) effort and willingness to invest in learning activities for comprehension of complex ideas [16]. Cognitive engagement helps determine students' persistence in the course and their intended degree major [17]. Social engagement [18] includes students' overt behaviors when participating in a social group or team [19]. The behaviors include both the interactions with other members and commitment to remain part of the group [20].

Engagement theory [6] provides a framework for teaching and learning in technology-mediated environments. The theory premise is that students can be better engaged in course learning activities through engaging interactions and the usage of technology tools. In conjunction with the conceptual framing of O'Brien and colleagues [7], the theory suggests the importance of students' meaningful interaction with both the course material and technology application. The engagement theory framework suggests that engagement may be recognized as a user engaging experience with the technology [6]. However, these experiences may go through different phases of engagement, including point of engagement (initial engagement), period of engagement, disengagement, and re-engagement. Additionally, the phase of engagement is often dependent on many more factors beyond usability experience, including feedback (may get by social interaction), intrinsic or extrinsic motivation (behavioral), positive affect (emotional), and perceived time (cognitive) [6], [7].

Furthermore, studies have associated both types of engagement, i.e., course-related and application, to the aspects of students' learning such as achievement [21], persistence [22], career aspirations [23]. Still, these two aspects of students' engagement are yet to be fully explored. The present study is premised on the fact that classroom environments are changing their culture, and instructors are using creative and different learning techniques, including various educational applications and tools to keep students engaged [24]. In this context, educational applications are active components of the learning environment used for a specific contextual reason. Examples of contextual reasons include but are not limited to a material sharing platform (e.g., learning management systems), a learning material (e.g., educational games), a mean or evaluator of interactions with peers (e.g., wikis, or CATME [25], [26]), or a catalyst to promote students understanding of course material (e.g., CourseMIRROR [27], [28]). Thus it is essential to see the relationship between these two perspectives of students' engagement. This study will investigate the relationship of these two students' engagement perspectives, i.e., course engagement (Course_Eng) and educational application engagement (EdApp_Eng), within the context of the first-year engineering course (FYE).

Research methods

For this semester-long study, we used a pragmatic lens. We used various methods in a correlational research design to explore the relationship between the two perspectives of students' engagement in an FYE course.

Site and participants

We collected data from 120 FYE students enrolled in a section of a required introductory engineering course in a large midwestern U.S public university. In the university, students are randomly placed in the sections. The course exposes students to fundamental programming concepts using MATLAB. Furthermore, the course builds students' understanding of the development of mathematical models to solve engineering problems using critical thinking and problem-solving abilities. The sample consisted of 83.33% male students and 16.67% female students. On ethnic variations, 21.67% of students were international, 61.67% were white American, and 16.67% were from groups collectively described as AHN (i.e., **A**frican Americans/Blacks, **H**ispanic/Latino(a), and **N**ative Americans/Alaskan Natives) [29], and 21.66% students who identified themselves with two or more races.

Engagement Measures

For the two perspectives of engagement, we used different measures. For Course_Eng, we relied on students' self-reported evidence from an extensively used instrument, "The Math and Science Engagement Scales" [13]. The instrument has previously been validated for engineering students and comprises 19 items [30]. We used the instrument as it captures students' engagement from all four dimensions as discussed in the literature using the subscales of behavioral (5 items), social (5 items), cognitive (4 items), and emotional engagement (5 items). We collected students' Course_Eng data twice in the semester, in a pre-post manner, i.e., at the beginning of the semester and once at the end of the semester. The data were collected using a 6-Likert scale value (95.5% average completion rate), where one indicated "strongly disagree," and six indicated "strongly agree."

For EdApp_Eng, the students enrolled in the course regularly used an application called CourseMIRROR [27], [31]. The app is designed to collect students' reflections after each lecture on two aspects 1) muddiest point – asking the students to describe their confusing points of the lecture and 2) point of interest – prompting the students to describe what they found most interesting in the lecture. The students voluntarily participated in the reflection submission process in 26 lectures and submitted 3430 student reflections in total (~55% completion rate). In the literature, the student engagement within the technology context is associated with their engaging experience and used goal completion (e.g., mastery of task; [32]) as an engagement measure. Aligned with the literature, this study used the number of times each student submitted the reflections as an app engagement measure for students' EdApp_Eng.

Procedure and Data Analysis

We modified the survey data used to measure the Course_Eng using standard procedures. First, we reverse-coded all the negatively worded items in all the subscales. This step was needed to bring all data items on the same measurement scale. Second, we examined the issues pertaining to outliers, skewness, kurtosis, multi-collinearity, singularity, and missing data. For all subscales, we found no outliers in the data. Additionally, skewness and kurtosis values were below or close to 1, indicating no issues. Third, we used correlation coefficients between variables to check for

multi-collinearity or singularity and found no problems between subscales. Finally, with less than 5% missing data, we mean imputed the values before analysis. In addition, for the analysis of two questions, we calculated the average values for pre and post-subscales, respectively. For example, we took the average of all 5 items for pre-behavioral engagement sub-scale (Pre_Beh), an average of 5 items of pre-emotional engagement (Pre_Emo), an average of 5 items of pre-social engagement (Pre_Soc), and an average of 4 items of pre-cognitive engagement (Pre_Cog). Similarly, we calculated the average of post-engagement subscales. For EdApp_Eng, we calculated the number of times students submitted the reflections out of the total of 26 lectures.

For the second research, we calculated the changes in students' Course_Eng, by subtracting the pre average of a subscale from the post average. For example, Beh_Changes = Average(5 items of Post-behavioral engagement) – Average(5 items of Pre-behavioral engagement). Similarly, we calculated changes in students' emotional engagement (Emo_changes), changes in social engagement (Soc_Changes), and changes in cognitive engagement (Cog_Changes). For all data analysis, we used IBM SPSS statistics (v. 28.0).

Results

To answer the first question of exploring the relationship between students Course_Eng, and EdApp_Eng, we initially calculated the Pearson product-moment correlation between pre-Course_Eng, post-Course_Eng, and EdApp_Eng. The results are presented in Table 1.

Table 1 Pearson product-moment correlation between Course_Eng and EdApp_Eng

	Course_Eng								
	Pre_Beh	Pre_Emo	Pre_Soc	Pre_Cog	Post_Beh	Post_Emo	Post_Soc	Post_Cog	EdApp_Eng
Pre_Beh	1.00	.454**	.645**	.819**	.623**	.315**	.518**	.623**	.189*
Pre_Emo	-	1.00	.441**	.481**	.301**	.553**	.115	.264**	.089
Pre_Soc	-	-	1.00	.676**	.405**	.261**	.451**	.455**	.043
Pre_Cog	-	-	-	1.00	.565**	.246**	.404**	.556**	.208**
Post_Beh	-	-	-	-	1.00	.479**	.597**	.774**	.036
Post_Emo	-	-	-	-	-	1.00	.278**	.438**	.018
Post_Soc	-	-	-	-	-	-	1.00	.707**	-.065
Post_Cog	-	-	-	-	-	-	-	1.00	.008
EdApp_Eng	-	-	-	-	-	-	-	-	1.00

*$p<0.05$, **$p<0.01$

The results of the correlation coefficients indicate a significant and positive correlation between two dimensions of students' pre-Course_Eng (i.e., Pre_Beh, and Pre_Cog) and EdApp_Eng, where the increase in students pre behavioral engagement and pre-cognitive engagement are directly related to increase in students' application engagement. However, there was a non-significant correlation between other dimensions of Pre Course_Eng and all dimensions of post-Course_Eng with EdApp_Eng.

To understand the relationship between students' course and app engagement, we conducted simple linear regressions between the dimensions of Course_Eng and EdApp_Eng. The results of the regression analysis are presented in Table 2. We used dimensions of Course_Eng as an independent variable and EdApp_Eng as the dependent variable.

Table 2 Results of regression analysis between Course_Eng and EdApp_Eng

Estimate	R^2	F(1,117)	B	SE	t	p
Pre_Beh	.036	4.339	2.521	1.210	2.083	.039*
Pre_Emo	.008	.927	.637	.662	.963	.338
Pre_Soc	.002	.212	.518	1.124	.461	.646
Pre_Cog	.043	5.269	2.512	1.094	2.295	.023*

*$p<0.05$, **$p<0.01$

The results indicate a significant relationship between students' Pre_Beh course engagement and EdApp_Eng. Also, there is a significant relationship between students' Pre-Cog engagement and EdApp_Eng. Although the values of R^2 are small, they indicate that 3.6% changes in students' EdApp_Eng are explained by the proportion of variance in the Pre behavioral engagement. Similarly, 4.3% variance in students EdApp_Eng is explained by the proportion of variance in students' cognitive engagement.

To answer the second research question and explore the degree of students' app engagement relationship with changes in course engagement, we conducted additional simple linear regressions between average changes of course engagement dimensions and EdApp_Eng. The results of the regression analysis are presented in Table 3. We used average changes in the dimension of Course_Eng as independent variables and EdApp_Eng as the dependent variable.

Table 3 Results of regression analysis between changes in Course_Eng and EdApp_Eng

Estimate	R^2	F(1,117)	B	SE	t	p
Beh_Changes	.032	3.358	-2.421	1.321	-1.832	.070*
Emo_Changes	.004	.475	-.486	.706	-.689	.492
Soc_Changes	.011	1.138	-1.192	1.117	-1.067	.289
Cog_Changes	.064	5.988	-2.930	1.197	-2.447	.016**

*$p<0.10$, **$p<0.05$

The results indicate a significant relationship between changes in students' behavioral engagement and EdApp_Eng. Also, there is a significant relationship between changes in students' cognitive engagement and EdApp_Eng. The R^2 values indicate that 3.2% changes in students' EdApp_Eng are explained by the proportion of variance in the changes of behavioral engagement. Similarly, 6.4% variance in students EdApp_Eng is explained by the proportion of variance in changes of students' cognitive engagement. However, these results indicate both dimensions of changes in students' course engagement cause a decrease in students' EdApp_Eng. We examined the mean difference between pre and post-course engagement for all four dimensions to explore these negative coefficients. The results are presented in Figure 1 (A-D). The graphs from pre to post indicate that all aspects of course engagement (measured with

different self-reported items) show a decrease from pre to post engagement except for the two items of the social engagement.

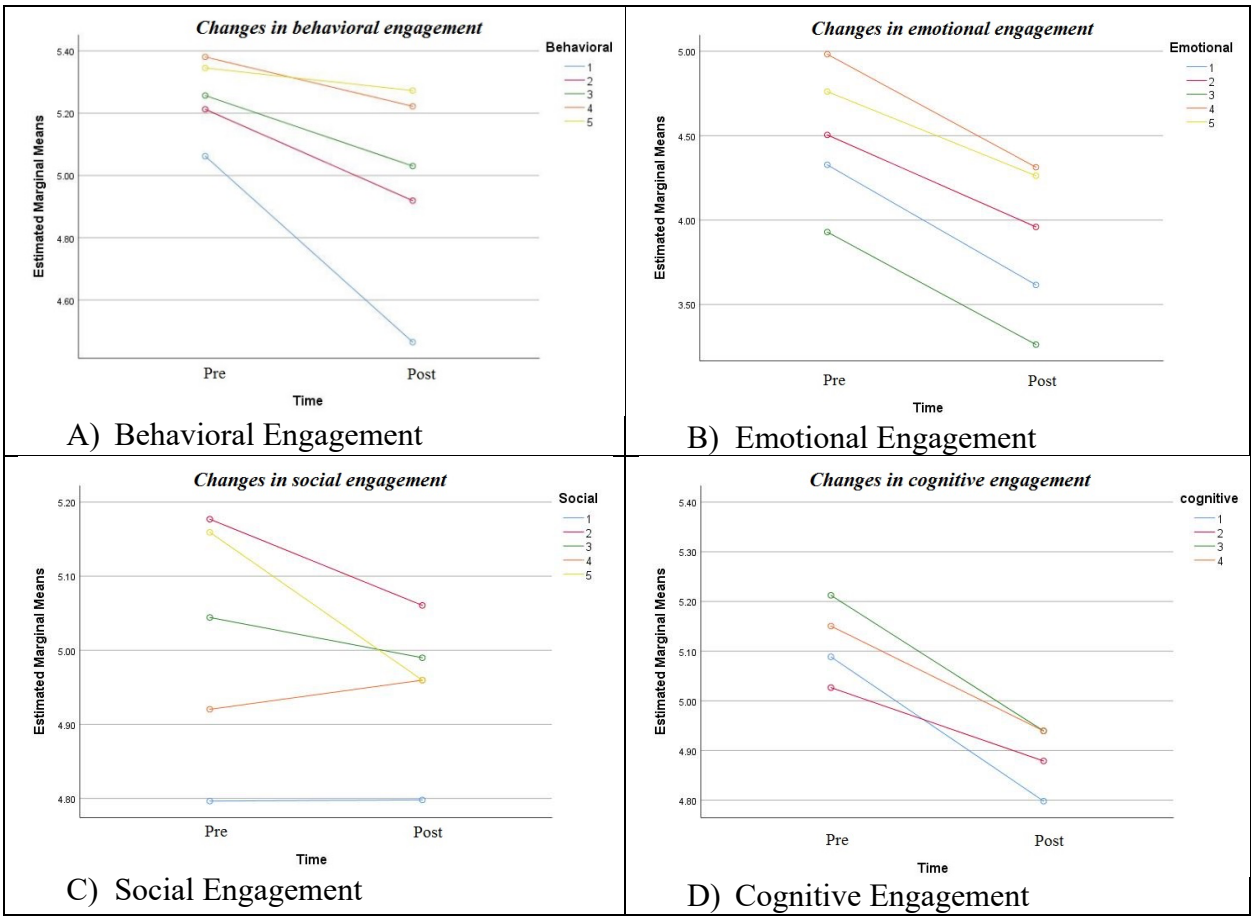

Figure 1 (A- D) Changes in Course_Eng from pre to post of four engagement dimensions

Discussion

This research study explored the relationship between two perspectives of students' engagement in an FYE course. We described these perspectives as students' course engagement and engagement with the educational application used in the course. We explained that course engagement describes students' meaningful interaction with content, material, and activities. In contrast, students' engagement with applications relies on students' meaningful interaction with the educational technology or application used in the course. We hypothesized that, as in the context of FYE, both perspectives deal with students' meaningful interaction and thus may have a relationship with one another. We conducted correlations and regressions between various dimensions of course engagement and students' educational app engagement. Besides the novelty in the research aspect of exploring this relationship, the study's results highlight important considerations. Students' behavioral and cognitive engagements were the two aspects that stood out within this investigation and had a relationship with students' engagement with the educational application. Looking deeper into the definition of these two dimensions of engagement, we noticed that behavior engagement is related to students participation, completion rates of activities, and attitudes towards work [4], [33]. As we measured students'

engagement with the app based on their submission rate, these may be because of students' behavior of completing the task at an adequate rate.

Similarly, cognitive engagement relies on the principles of use and effort to invest in learning activities [3], [15], which may help students use the application. Besides a relationship among students' behavioral engagement, cognitive engagement, and educational app engagement, for both pre-engagement and changes in engagement, we observed that changes in engagement negatively impact students' app engagement. Based on existing literature, one probable explanation could be students may go through different phases of engagement in the course [6], [7]. It is possible that at post-engagement survey time, students may have been in a different phase of engagement (e.g., period of engagement, disengagement, or re-engagement) from pre-survey (initial engagement). Our further explorations indicated a decline from students' pre- to post-engagement for all dimensions, indicating students' disengagement or the beginning of the re-engagement phase. As the acquisition of these phases can be due to multiple factors, they probably are worth exploring during the entire semester.

These results are also interesting as results are indicative of a decline in students' engagement from per to post class. The reasons for such a decline in engagement could be related to students' expectations, harder course content and topics (e.g., programming [34]), or particular learning activities employed in the course[35]. Another explanation could be due to students' higher level of engagement at the entry-level based on their past performances in high school, higher scores in standardized tests, and getting admission to one of their top choice universities [36], causing the rapid change into the next phase of engagement (e.g., disengagement). Besides, the students self-reported their engagement introspectively and retrospectively, which relies on their generalizations about the course and situation of what they believe they will do or did in a situation. These generalizations could be influenced by students' ability to relate the questions with their experience and learning in a conscious manner [37].

Limitations and Future Directions

Based on the discussion of the results, the study has several limitations and corresponding future directions. First, the study uses the data of one section of an FYE class, thus having a relatively small sample size. Future studies can focus on a larger sample size in multiple sections of the same course or various courses. Also, with larger sample sizes, future studies may account for gender and ethnicity-based variations in students' course engagement and educational app engagement.

Second, in this study, we used one application, i.e., CourseMIRROR, to investigate the potential relationship between students' course engagement and app engagement. Future studies may consider various other applications consistently used in educational courses and see their relationship with different engagement perspectives. Third, in this study, we relied on students' self-reported evidence of course engagement. We did not include process data such as classroom observations(e.g., [38]), teachers' records of student engagement, etc. Although the literature supports the self-reported evidence for valid and reliable results [39], future studies may add other sources of information for accuracy and holistic explanation.

In addition, we suggest the in-depth examination of students' course engagement with other forms of engagement (e.g., cognitive engagement; reflection quality) based on phases of the engagement. As in this study, we collected the course engagement survey at two-time points, and we may have missed certain aspects of the period of engagement and re-engagement.

Conclusion

The research study highlights the importance of multifaceted, multidimensional, and meta construct of students' engagement. This study discussed the role of various perspectives of engagement in students' journeys within the context of FYE education. These varying engagement perspectives are timely and essential in this era of the ongoing pandemic, heavy reliance on technology tools, and use of other modalities in higher education. With every new day, instructors across the globe are looking for ways to enhance students' engagement in classes within new modalities. However, we argue that using these educational technology tools and new modalities should be contingent on many factors, including how these tools are related to students' course engagement and content [40]. Based on existing literature that suggests that positive experiences enhance students' motivational aspects, we urge to investigate the relationship of new methods of instruction with students motivational constructs, including engagement [41]. We argue that without such evaluations, the continuous use of unrelated perspectives may result in frustrating and stressful students' experiences.

Acknowledgment

We want to acknowledge the support of the Institute of Education Sciences provided by a grant (R305A180477) to conduct the research in the paper. The opinions expressed in this article do not represent the views of the U.S. Department of Education.

References

[1] S. Anwar, M. Menekse, and A. A. Butt, "Perceived motivational constructs and engineering students' academic performance," in *Proceedings of 2020 ASEE Virtual Annual Conference Content Access*, Jun. 2020.

[2] L. J. Rylands and D. Shearman, "Mathematics learning support and engagement in first year engineering," *Int. J. Math. Educ. Sci. Technol.*, vol. 49, pp. 1133–1147, 2018, doi: 10.1080/0020739X.2018.1447699.

[3] C. A. Watterson, W. N. Browne, and D. A. Carnegie, "Steps to increase student engagement and retention in first year engineering," in *Proceedings of 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, Aug. 2013, pp. 1–6. doi: 10.1109/TALE.2013.6654388.

[4] A. L. Reschly and S. L. Christenson, "Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct," in *Handbook of Research on Student Engagement*, Springer, 2012, pp. 3–19.

[5] J. L. Meece, P. C. Blumenfeld, and R. H. Hoyle, "Students' goal orientations and cognitive engagement in classroom activities.," *J. Educ. Psychol.*, vol. 80, pp. 514–523, 1988, doi: 10.1037/0022-0663.80.4.514.

[6] G. Kearsley and B. Shneiderman, “Engagement theory: A Framework for technology-based teaching and learning,” *Educ. Technol.*, vol. 38, pp. 20–23, 1998.
[7] H. L. O’Brien and E. G. Toms, “What is user engagement? A conceptual framework for defining user engagement with technology,” *J. Am. Soc. Inf. Sci. Technol.*, vol. 59, pp. 938–955, 2008, doi: https://doi.org/10.1002/asi.20801.
[8] J. A. Fredricks, P. C. Blumenfeld, and A. H. Paris, “School engagement: Potential of the concept, state of the Evidence,” *Rev. Educ. Res.*, vol. 74, pp. 59–109, Mar. 2004, doi: 10.3102/00346543074001059.
[9] M.-T. Wang, J. B. Willett, and J. S. Eccles, “The assessment of school engagement: Examining dimensionality and measurement invariance by gender and race/ethnicity,” *J. Sch. Psychol.*, vol. 49, pp. 465–480, Aug. 2011, doi: 10.1016/j.jsp.2011.04.001.
[10] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, “Persistence, engagement, and migration in engineering programs,” *J. Eng. Educ.*, vol. 97, pp. 259–278, Jul. 2008, doi: 10.1002/j.2168-9830.2008.tb00978.x.
[11] J. P. Connell, “Context, self, and action: A motivational analysis of self-system processes across the life span.,” in *The Self in Transition: Infancy to Childhood.*, Chicago, IL, US: University of Chicago Press, 1990, pp. 61–97.
[12] E. Deci and R. Ryan, “What is the self in self-directed learning? Findings from recent motivational research,” *Concept. Self-Dir. Learn. Theor. Concept. Consid.*, pp. 75–92, 2000.
[13] M.-T. Wang, J. A. Fredricks, F. Ye, T. L. Hofkens, and J. S. Linn, “The Math and science engagement Scales: Scale development, validation, and psychometric properties,” *Spec. Issue Stud. Engagem. Learn. Theor. Methodol. Adv.*, vol. 43, pp. 16–26, Jun. 2016, doi: 10.1016/j.learninstruc.2016.01.008.
[14] J. J. Appleton, S. L. Christenson, D. Kim, and A. L. Reschly, “Measuring cognitive and psychological engagement: Validation of the student engagement instrument,” *Motivation*, vol. 44, pp. 427–445, Oct. 2006, doi: 10.1016/j.jsp.2006.04.002.
[15] J. A. Fredricks and W. McColskey, “The Measurement of student engagement: A Comparative analysis of various methods and student self-report instruments,” in *Handbook of Research on Student Engagement*, S. L. Christenson, A. L. Reschly, and C. Wylie, Eds. Boston, MA: Springer US, 2012, pp. 763–782. doi: 10.1007/978-1-4614-2018-7_37.
[16] L. Corno and E. B. Mandinach, “The role of cognitive engagement in classroom learning and motivation,” *Educ. Psychol.*, vol. 18, pp. 88–108, Jun. 1983, doi: 10.1080/00461528309529266.
[17] J. C. Richardson and T. Newby, “The Role of students’ cognitive engagement in online learning,” *Am. J. Distance Educ.*, vol. 20, pp. 23–37, Mar. 2006, doi: 10.1207/s15389286ajde2001_3.
[18] J. A. Fredricks *et al.*, “Using qualitative methods to develop a survey measure of math and science engagement,” *Spec. Issue Stud. Engagem. Learn. Theor. Methodol. Adv.*, vol. 43, pp. 5–15, Jun. 2016, doi: 10.1016/j.learninstruc.2016.01.009.
[19] W. R. Avison, J. D. McLeod, and B. A. Pescosolido, *Mental health, Social mirror*. Springer, 2007.
[20] S. Zhang, H. Jiang, and J. M. Carroll, “Integrating online and offline community through facebook,” in *2011 International Conference on Collaboration Technologies and Systems (CTS)*, May 2011, pp. 569–578. doi: 10.1109/CTS.2011.5928738.

[21] F. H. Wang, “An exploration of online behaviour engagement and achievement in flipped classroom supported by learning management system,” *Comput. Educ.*, vol. 114, pp. 79–91, Nov. 2017, doi: 10.1016/j.compedu.2017.06.012.
[22] A. Sithole, E. T. Chiyaka, P. McCarthy, D. M. Mupinga, B. K. Bucklein, and J. Kibirige, “Student attraction, persistence and retention in STEM programs: Successes and continuing challenges.,” *High. Educ. Stud.*, vol. 7, pp. 46–59, 2017.
[23] M. Almeda, R. S. Baker, and others, “Predicting student participation in STEM careers: The Role of affect and engagement during middle school.,” *J. Educ. Data Min.*, vol. 12, pp. 33–47, 2020.
[24] M. B. Gilboy, S. Heinerichs, and G. Pazzaglia, “Enhancing student engagement using the flipped classroom,” *J. Nutr. Educ. Behav.*, vol. 47, pp. 109–114, Jan. 2015, doi: 10.1016/j.jneb.2014.08.008.
[25] M. W. Ohland *et al.*, “The Comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self- and peer evaluation,” *Acad. Manag. Learn. Educ.*, vol. 11, pp. 609–630, Dec. 2012, doi: 10.5465/amle.2010.0177.
[26] R. A. Layton, M. L. Loughry, M. W. Ohland, and G. D. Ricco, “Design and validation of a web-based system for assigning members to teams using instructor-specified criteria.,” *Adv. Eng. Educ.*, vol. 2, p. n1, 2010.
[27] X. Fan, W. Luo, M. Menekse, D. Litman, and J. Wang, “CourseMIRROR: Enhancing large classroom instructor-student interactions via mobile interfaces and natural language processing,” in *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, New York, NY, USA, 2015, pp. 1473–1478. doi: 10.1145/2702613.2732853.
[28] S. Anwar and M. Menekse, “Unique contributions of individual reflections and teamwork on engineering students’ academic performance and achievement goals,” *Int. J. Eng. Educ.*, vol. 36, pp. 1018–1033, May 2020.
[29] T. L. Williams, “‘Underrepresented minority’ considered harmful, racist language.” cacm.acm.org. https://cacm.acm.org/blogs/blog-cacm/245710-underrepresented-minority-considered-harmful-racist-language/fulltext (accessed May 16, 2022).
[30] S. Anwar, “Role of different instructional strategies on engineering students’ academic performance and motivational constructs,” Ph.D. dissertation, Purdue University, West lafayette, IN, 2020.
[31] X. Fan, W. Luo, M. Menekse, D. Litman, and J. Wang, “Scaling reflection prompts in large classrooms via mobile interfaces and natural language processing,” in *Proceedings of the 22nd International Conference on Intelligent User Interfaces*, New York, NY, USA, 2017, pp. 363–374. doi: 10.1145/3025171.3025204.
[32] X. L. Pham and G. D. Chen, “PACARD: A New interface to increase mobile learning app engagement, distributed through app stores,” *J. Educ. Comput. Res.*, vol. 57, pp. 618–645, 2019, doi: 10.1177/0735633118756298.
[33] J. J. Appleton, S. L. Christenson, D. Kim, and A. L. Reschly, “Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument,” *J. Sch. Psychol.*, vol. 44, pp. 427–445, 2006.
[34] M. Guzdial, “Programming environments for novices,” *Comput. Sci. Educ. Res.*, vol. 2004, pp. 127–154, 2004.

[35] A. A. Butt, S. Anwar, and M. Menekse, “Work in Progress: STEM students’ experiences with educational technology tools,” in *Proceedings of 2021 ASEE Virtual Annual Conference Content Access*, Jul. 2021.
[36] H. Geraedts, W. van de Groep, and E. Hueting, “Motivation blockers of first year Mechanical Engineering students at the Fontys University of Applied Sciences,” in *Proceedings of the 43rd Annual SEFI Conference*, Jun. 2015.
[37] A. Roth, S. Ogrin, and B. Schmitz, “Assessing self-regulated learning in higher education: a systematic literature review of self-report instruments,” *Educ. Assess. Eval. Account.*, vol. 28, pp. 225–250, Aug. 2016, doi: 10.1007/s11092-015-9229-2.
[38] S. Anwar and M. Menekse, “A systematic review of observation protocols used in postsecondary STEM classrooms,” *Rev. Educ.*, vol. 9, pp. 81–120, 2021.
[39] S. R. Porter, “Self-reported learning gains: A theory and test of college student survey response,” *Res. High. Educ.*, vol. 54, pp. 201–226, 2013.
[40] R. Kandakatla and R. A. Streveler, “T-CAP: Framwork to design student-centric courses using educational technology tools,” in *Proceedings of the 49th Annual SEFI Conference*, Sep. 2015, pp. 951-959.
[41] I. V. Alarcón and S. Anwar, “Situating multi-modal approaches in engineering education research,” *J. Eng. Educ.*, vol. 111, pp. 277–282, Apr. 2022, doi: 10.1002/jee.20460.