Exploring Relationships Between Academic Engagement, Application Engagement, and Academic Performance in a First-Year Engineering Course

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***Abstract*— This work-in-progress research paper examines the relationship between two aspects of students' engagement and academic performance.**

With the boom of technology-mediated learning environments, many educational applications are integrated into STEM courses. However, the effectiveness of these applications in the learning environments is contingent upon factors including but not limited to applications' ease of use, relevance to courses, students' engagement with the application, and perceived value of the application in the context of students' learning. This work-in-progress paper uses two aspects of engagement in a mobile technology-mediated learning environment and explores their relationship with students' academic performances. The two perspectives of engagement include 1) students' engagement with the course – Academic Engagement and 2) students' engagement with the application used in the course – Application Engagement. We collected the data from 110 first-year engineering students enrolled in a required engineering class programming in MATLAB. Students self-reported their academic engagement on four dimensions: behavioral, emotional, social, and cognitive. In addition, students used a mobile application called CourseMIRROR. The application prompted students to write their reflections on each lecture throughout the semester, asking about its interesting or confusing points. The application uses Natural Language Processing (NLP) algorithm to create the summaries of these reflections. For application engagement, we used the number of times students viewed the summary through embedded data analytics in the CourseMIRROR application. For students' academic performance, we used the students' total scores in the course. We hypothesize that these two engagement perspectives are related to the students' academic performance. Specifically, the study will be guided by the following research questions: 1) To what degree do students' academic and application engagement relate to their academic performance? And 2) Do students with high engagement (i.e., academic or application) perform better in their exams? We analyzed the data using Pearson product-moment correlation and multiple regression to predict the students' academic performance and its relationship with students' academic engagement and application engagement. This work-in-progress paper presents the results of these analyses and their implications and provides future research directions.

Keywords*— *application engagement, first-year engineering, engagement, academic performance, educational application.

I. Introduction (*Heading 1*)

The change in the academic environment was eminent during the pandemic, with more emphasis has been placed on the effective integration of educational technology tools. More and more classes started to shift towards technology-mediated learning environments to improve students' learning and engagement.

Technology-mediated learning environments are carving their path within this current era of ongoing Covid-19 pandemic and new normal times. New educational applications are commonly introduced and integrated into different courses. However, primarily these applications contribute in two ways. They are either introduced to facilitate course management (including a learning management system or virtual tools for delivering lectures) or enhance students' experience with the course content and material (including domain-specific applications).

It is noteworthy that the impact of this integration and re-shaping of learning environments is multi-fold on students' engagement. Besides academic engagement, students are also required/ or asked to stay engaged with educational application tools. With this high integration and use of technology in the classroom, student engagement cannot be considered in either standalone academic or application context. It is equally important to understand how each of these engagement aspects impacts each other [1], [2].

Since the inception of the term engagement, the term has been conceptualized in many ways [3], [4]. These conceptualizations varied on two fundamental characteristics: 1) context and environment in which engagement is described and 2) indicators of engagement in the context [5]. For example, various engagement terms are being used in the case of context and environment characteristics. These terms include students' engagement, academic engagement, school engagement, and application engagement. For all these terms, engagement has also been conceptualized based on two distinct indicators, i.e., behavior [6] or psychological [7]. For example, behavior indicators described school engagement [8] as students' participation in activities, while psychological indicators related engagement with students' positive feelings about the school.

Similarly, academic engagement [9] could be described using behavior and psychological indicators as students' active participation in course work or students' perceptions and feelings about the coursework. Furthermore, application engagement [10], [11] could be described as students' participation or interaction with the tasks associated with the application or their positive attitude and eagerness to use it [1]. Also, two important things were notable across these

conceptualizations and their characteristics. First, these conceptualizations focused on students' meaningful interaction with the environment (academic, school, or application) through participation or perceptions about behavior or psychological indicators. Second, in the academic context, students' engagement across its conceptualization has been an important construct in students learning outcomes, academic experiences, and reducing achievement gaps.

Considering these two engagement conceptualizations (academic and application) as two facets of students' engagement, this work-in-progress paper emphasizes exploring the relationship between them. We approached these facets by focusing on student engagement characteristics (context and indicators). For the context variation, in this paper, we use two categories of students' engagement 1) academic engagement and 2) application engagement. For indicators variation, we used students' behavioral and psychological indicators to measure their perception of the engineering course work (academic engagement) and application engagement. For example, we used students' self-reported evidence of course engagement, where students described their behavior towards the course and the application. Students also self-reported their feelings about the course and application. This work-in-progress paper is timely and intuitive as it explores the relationship between two conceptualizations of students' engagement using variant contexts and indicators in a single engineering course. Also, as students' engagement could be associated with academic performance, We hypothesized that these conceptualizations could be associated with students' academic performance in engineering programming courses. More specifically, we addressed the following research questions:

1. To what degree do students' academic and application engagement relate to their academic performance?
2. Do students with high engagement (i.e., academic or application) performs better in their exams?

II. Theoretical Framework and Literature Review

As the study's premise is situated in students' engagement and we explore the two aspects of engagement, we conceptualize the theoretical framework according to the context and indicator-based variations. Drawing from principles of students' engagement and self-system motivation theory [12], the students' positive behaviors (behavioral), positive emotional reactions (emotional), willingness to participate in activities (cognitive), and commitment to work with peers and instructors (social) are major four dimensions of students' engagement. In this way, engagement can be viewed as a multifaceted, multidimensional phenomenon with interrelated dimensions. Using the self-system, the students can self-report the behavior and psychological indicator of academic engagement on all four dimensions, i.e., behavioral, emotional, cognitive, and social, towards learning activities and material (academic engagement) [13]. Also, students can be observed for their behavior-based indicators while they are engaged in academic tasks.

Existing studies have used these four dimensions of engagement [5]. However, limited studies have captured all four aspects of engagement in a single study [3]. For example, Appleton and colleagues [14] provided an instrument to measure students' cognitive and behavioral engagement dimensions. However, they didn't capture the social dimension of engagement within their instrument. Similarly, many studies have used one or two dimensions of this multifaced phenomenon and have ignored the other aspects in the context, e.g., [15]–[17].

Taking the lens of engagement theory [18], which describes engagement in the context of a technology-mediated environment, both behavior [6] and psychological [7] indicators of engagement can be captured. The premise of engagement theory is based on students' interaction and usage of technology in a meaningful way [11], [18]. The application can collect data on meaningful usage for behavior indicators, while for psychological indicators, students can self-report their willingness to use the application.

Prior studies have associated academic and application engagement with factors such as students' achievement [19] or retention in the program [20]. However, most studies have explored either academic or application engagement. With changing cultures and the boom in the technology-mediated learning environment, both types have started to co-exist, where both have their specific influence on students' academic learning experience. Thus, it is essential to see the relationship between these two perspectives of engagement with students' academic performance in the same class context. As a work-in-progress paper, this study explores the preliminary results of such a relationship between academic engagement, application engagement, and students' academic performance.

III. Research Methods

For this work-in-progress paper, we designed a cross-sectional study to explore the relationship between students' academic engagement, application engagement, and academic performance.

A. Site and participant

In this study, 110 engineering students voluntarily participated. Students were enrolled in a required introductory first-year engineering course at a large public university in Midwest, USA. Students were selected as they were exposed to a technology-mediated learning environment and studied the fundamental programming concepts using MATLAB. Also, the course introduces students to problem-solving and develops their understanding of mathematical models. The sample comprised 66.4% male students, 27.3% female students, 2.7% non-binary students, and 0.9% who preferred not to disclose their gender. On ethnic variations, 8.2% of students were international, 61.8% were white American, 20.0% were Asian American, and 4.5% were from groups collectively described as AHN (i.e., African Americans/Blacks, Hispanic/Latino(a), and Native Americans/Alaskan Natives) [21]. Further, 3.6% of students identified themselves with two or more races, and 1.8% preferred not to disclose their ethnicity.

B. Measures

The data were collected on three variables 1) academic engagement, 2) application engagement and 3) academic performance. Students' voluntary participation collected all the data.

For students, academic engagement using psychological indicators, we used the tailored version of "The Math and Science Engagement Scales" [13] instrument of students' engagement comprised four subscales of behavioral, emotional, cognitive, and social engagement. The scale has been previously validated for engineering students [5], and we collected the data on 23 items. Students self-reported their academic engagement using a 6-Likert scale, where one indicated "strongly disagree," and six indicated "strongly agree."

For the application engagement, students used an application called CourseMIRROR [22]–[24]. The application was designed using Reflection-Informed-Learning and Instruction (RILI) framework and collects students' reflections after each lecture. Later, the application summarizes students' reflections for each lecture using Natural Language Processing (NLP) algorithms. These summaries are made available to both students and instructors. The premise of the application suggests that the summary component is an essential factor in students' learning and feedback. This summary helps provide a quick overview to the instructor of the problematic and exciting concepts of the lecture. It allows them to revise their following lecture and provide feedback to students. This summary allows students to understand the course's difficulties and conceptually complex components in light of their peers' struggles. Considering that application engagement is based on students' meaningful interaction with the course, we used the CourseMIRROR analytics of whether or not a summary is viewed by the student for each lecture, where 0 indicated not viewed, and 1 indicated summary is viewed by the student at least once. In this paper, we didn't account for the number of times the student viewed the summary.

We used students' total scores obtained in the course for students' academic performance. The maximum score was 1015, and the minimum was zero for the total score (academic performance).

C. Procedure and Data Analysis

We modified the academic engagement data using standard reverse coding procedures and tested for regression analysis assumptions. In particular, we observed the issues of outliers, skewness, kurtosis, multi-collinearity, singularity, and missing data. We found no outliers in the data for all subscales, and values of skewness and kurtosis were below one, indicating no issues. We had no missing data. For this preliminary exploration, we took the average of all the items within each subscale of the instrument.

Additionally, for application engagement, we calculated the total number of times students viewed the summary of lectures, indicating how many lectures students viewed the created summary.

We conducted two analyses to understand the relationship between academic engagement, application engagement, and academic performance. The first set of analyses was conducted using Person product-moment correlation. We calculated the coefficients between three variables. Additionally, in the second set, we conducted multiple linear regression to understand the role of academic engagement and application engagement on student academic performance scores with the dependent variable of students' total exam score and independent variables as academic engagement and application engagement. For all data analysis, we used IBM SPSS statistics (v. 28.0).

IV. Preliminary Results

To answer the research questions, we first calculated the Pearson product-moment correlation between the four dimensions (behavior, emotional, social, and cognitive) of academic engagement, application engagement, and academic performance. We calculated the Person product-moment correlation to determine the strength and direction of the linear relationship between variables. The results are presented in Table 1. It is noteworthy that we removed the redundant information from Table 1 for clarity purposes.

The results indicate significant correlations between all four aspects of academic engagement. Also, a significant correlation was found between application engagement and academic performance. However, academic engagement didn't correlate with students' academic performance or application engagement.

TABLE 1 CORRELATIONS OF ENGAGEMENT (ACADEMIC AND APPLICATION) AND ACADEMIC PERFORMANCE

	Academic Engagement				
Constructs	***Beh.***	***Emo.***	***Soc.***	***Cog.***	**Application Engagement**
Emotional	.665**				
Social	.657**	.615**			
Cognitive	.750**	.709**	.681**		
Application Engagement	.063	-.008	-.085	.031	
Academic performance	.159	.054	.055	.151	.761**

*p<0.05, **p<.01

Additionally, to understand whether students with higher engagement (course or application) show higher academic performance, we conducted multiple linear regression with five predictors (behavioral, emotional, social, cognitive, and application engagement) and one dependent variable as student academic performance. The results are presented in Table 2.

The linear combination of these five predictors was significant with academic performance with $F(5,104) = 31.394$, $p<.001$. The R^2 value was .601, indicating that the linear combination of the predictors can account for 60.1% of the variance in academic performance. The estimated values indicated that application engagement was significantly related to academic performance and accounted for the most variance.

TABLE 2 RESULTS OF REGRESSION ANALYSIS BETWEEN ACADEMIC ENGAGEMENT, APPLICATION ENGAGEMENT, AND ACADEMIC PERFORMANCE

Estimate	**β**	**SE**	**t**	**p**	**sr^2**
Behavioral	.039	110.605	.380	.705	.024
Emotional	-.089	89.010	-.959	.340	-.059
Social	.073	99.792	.793	.429	.049
Cognitive	.113	117.517	1.044	.299	.065
Application Engagement	.761	.154	12.077	<.001**	.748

*p<0.05, **p<0.01

V. Discussion and Conclusion

This work-in-progress paper explored the relationship between students' academic engagement, application engagement, and academic performance. We described engagement as meaningful interaction with either academic

content, material, activities, or the application used in a technology-mediated learning environment. Besides context and environment-based variation, we also described the variation of indicators that may be captured for measuring students' engagement: behavior-based indicators [6] or psychological indicators [7]. This study used behavior-based indicators for students' application and self-reported behavior, and psychological indicators for academic engagement.

The study results indicated a significant relationship between students' application engagement and academic performance. To our surprise, the same didn't hold for academic engagement. Also, academic engagement was not found to be related to application engagement. One probable explanation could be rooted in using a different measuring indicator for both types of engagement, i.e., behavior [6] or psychological [7]. The other explanation could be the nature of the engineering course, which was based on programming aspects and is considered intrinsically hard for students [25]. Also, we relied on one data point for all four subscales of academic engagement. Students' engagement may have been in different phases of engagement during the course, such as disengagement, or re-engagement, which may have been the reason for the current results [18]. However, more explorations are needed to get conclusive results.

The results of this study may be viewed with some limitations and future directions, especially as this is work in progress study. The future full paper could expand in many ways. For example, the full paper can focus on changes in students' application and academic engagement over time. Also, the full paper may include a more extensive data sample to account for gender and ethnicity-based variations. Additionally, the full paper could emphasize the randomized control experiment for research design and may use quasi-experimental or experimental design for a more cohesive understanding. In addition, future studies may use the same type of indicators for both and see the relationship instead of behavioral and psychological variations. Also, in this work-in-progress paper, the dataset comprised students from one course and one university. For more accuracy, future studies can focus on a larger sample size in multiple courses across universities.

Moreover, although we used the multidimensional construct of academic engagement, we used only one measure of academic engagement, application engagement, and academic performance in this study. In the full paper and future studies, we may use multiple measures and examine their relative effect. Also, we will include the process data such as classroom observations using structured and unstructured protocols [26] for capturing students' engagement from other perspectives as well. This study was cross-sectional, and only one data point for all four subscales of academic engagement was considered. Future studies may collect and analyze data that is collected at multiple time points in the course.

Although this study highlighted the importance of various engagement characteristics such as multiple types, multiple dimensions, multiple indicators, and multiple phases, the study provides the initial explorations. With the multifaceted nature of engagement, it is essential to dive into more forms with explorations through new and novel methodologies [27].

It is also noteworthy that this study gives invaluable insights about modifications to CourseMIRROR design, features, and usage in classes. The results found no relationship between academic and application engagement, which probably could be achieved for students' behavioral, social and cognitive engagement with modifications to the CourseMIRROR application, and its usage. As the CourseMIRROR application uses the RILI model, both reflection writing and feedback process can be made more personalized for students, so they engage better with the academic material and eventually may improve the educational value of the application.

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