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Demographic Mediation of the Relationship Between Engagement and Performance in a Blended Dynamics Engineering Course

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ABSTRACT

CONTEXT
This paper examines an engineering dynamics course at Purdue University that was specifically designed to create an active, blended, and collaborative environment. In addition to in-person classes and support, students have access to blended content such as solution videos, mechanics visualizations, a course discussion forum, and interactive simulations.
PURPOSE
Many studies have shown that students' engagement in an online discussion forum enhances their learning performance (Davies & Graff, 2005; Hrastinski, 2008). However, our previous research showed that students' engagement in the online forum of our dynamics course differed significantly across students' demographics. We showed that women, white, or Asian American students were more likely to be involved in online discussions than men, international, or Hispanic students (Duan et al., 2018). In this paper, we take the previous analysis further by examining whether the observed differences in online student engagement mediate or moderate student performance.
APPROACH
To answer our research question, we will first investigate the mediation effect by creating two models. A first model with race/international status as the mediating variable and gender identity as a control variable, and a second model with gender identity as the mediating variable and race/international status as a control. Second, we will investigate the moderation effect of demographic factors by creating a regression model including interaction terms to show the relationship of each demographic's discussion forum engagement to overall performance. The goal of investigating these interaction terms is to determine if a moderating relationship exists where demographic factors impact online engagement, which in turn impact course performance.
CONCLUSIONS
We find that gender identity is the only significant demographic factor that moderates the effect of a student's engagement on their performance. Based on the findings of our previous work, students of various racial and ethnic identities do engage differently in the discussion forum. However, this analysis was unable to detect any significant difference in student engagement based on demographics. Our paper contributes to understanding the mechanisms through which students' engagement can translate into academic performance by focusing on their demographic background. The moderating role of students' demographic background calls for a more targeted design of instructional tools in blended and collaborative environments to better support students from various demographic backgrounds.
KEYWORDS
Mediation Analysis, Dynamics Course, Demographics

Introduction

Freeform is an Active, Blended, Collaborative (ABC) that started in the School of Mechanical Engineering at Purdue University in 2008 in order to incorporate Active, Blended, and Collaborative elements into a typical dynamics course. The ABC approach was later expanded to include more courses in the mechanics sequence and has since been expanded to additional schools (DeBoer et al., 2016). A Freeform course includes hybrid textbooks paired with an interactive online learning environment and course discussion forums (Rhoads et al., 2014). Previous studies have looked at student data collected from multiple semesters and have examined both student (Stites et al., 2019) and instructor (DeBoer et al., 2016) behaviours within the course. Among student behaviours, prior research has concluded that the "ABC" approach contributes to a higher passing rate (Rhoads et al., 2014). Further, these studies have found some differences in course engagement based on demographics when engagement is measured through a binary variable of participation or non-participation in the discussion forum (Duan et al., 2018). Differences have also been found in engagement (where engagement was defined as participation in the various course resources) based on preference for how students engage with course resources (Stites et al., 2019). These studies concluded that women were more engaged with the online discussion forum than men. Likewise, Asian Americans engaged the most while underrepresented minoritized students (specifically Hispanic, Latino, and African American students within this study) engaged the least when compared to their representation in class overall (Duan et al., 2018).

Literature Review

Many studies suggest that engaging in a collaborative online learning environment has the potential to enhance students' learning (Berger & Wild, 2016; Hiltz, 2019; Williams et al., 2006). By engaging with their classmates, students could learn from and assist one another in the learning process and therefore improve their academic performance (Yuan & Powell, 2013). However, previous research has also shown that online learning environments do not benefit all students in the same way. In fact, Ke and Kwak (2013) show how students' ethnicities correlate to their participation in an online learning forum. Underrepresented minority groups who participated less in the course forum also reported lower levels of satisfaction with the web-based and distance-learning class, which the authors concluded was due to the important role discussion forums served in these courses as a place for students to interact with one another and the professors. Ke and Kwak's work also showed how international students were less comfortable engaging in public online spaces, and thus engaged less in online discussion forums (Ke & Kwak, 2013). These differences in students' engagement based on their demographic factors might result in differences in academic performances in the context of a blended course. In this paper, we will study whether differences in students' engagement across demographic factors mediates or moderates students' course performance. The context of this study is the innovative Active, Blended, and Collaborative (ABC) dynamics learning environment called Freeform.

Methods

Our dataset includes transcript-level data of all students enrolled in dynamics (2000-present), gradebook-level data for dynamics performance for nearly all of the offerings of the course (2012-present), data from various surveys (2015-present), performance on concept inventory and fundamentals exams (2015-present), discussion forum engagement data (most semesters 2015-present), and student-level data obtained from university data sources (demographics, admissions data; 2000-present). For this study, we subset this data to include only: (i) students who consented to participate in the study, and (ii) students enrolled

in semesters for which we collected discussion forum data. We further confined the dataset for this study to include only Spring semesters because students, according to the standard plan of study, enrolled in dynamics in the Spring of the second year. The dataset includes Spring data from 2015, 2017, 2018, 2019, 2020. All students from these semesters are included in the dataset regardless of their level of participation in the discussion forum.

This study uses forum activity, demographic information, and course grades as variables to determine the mediating effect of demographic variables for engagement with the discussion forum on performance. Demographic information will include gender identity and race/international status. Our institution categorizes international students' race/ethnicity as 'international' without gathering/storing additional information on their racial identity. Additionally, to protect student identities and create comparable groups within the dataset, student racial and ethnic identities had to further be simplified to White, Asian American, Underrepresented Minoritized Students (URM), and International Students. Underrepresented Minoritized Students (URM) included Hispanic, Latino, African American, and those who were categorized in the "Other" category as had been done in previous analyses of this data (Duan et al., 2018). These simplifications allow for a larger overview of mediation and moderation effects on how students participate and perform in the course. To perform these analyses,the groups being compared must be of significant enough size. The fact that these URM groups are so small (none are over 100 and some are as small as 19) reflects a lack of diversity represented in these courses. This problematic grouping into the larger category of URM does potentially obscure important data on how students experience their racial and ethnic identities within the classroom. We derived participant sex from institutional data, which only allows individuals to specify 'male' or 'female'. We understand that this practice is problematic and does not allow individuals to express the full diversity of gender identities.

Engagement with the discussion forum will be defined through pagerank, a social network analysis method explained below. Pagerank is an ordinal measurement.Thus, pagerank is best used in comparison of students to one another and gives less information on its own (Stevens, 1946). The authors used GEPHI 0.9.2 to calculate each student's pagerank, which shows their level of engagement compared to others in their same semester (Lee et al., 2021). Students are ranked based on the number of posts they make and the relative importance of their posts (examined through number of responses they receive and the relative importance of the respondents). In other words, posts that come from more active respondents who generate more comments are ranked higher. For instance, one student may only post questions such as "What day is the final exam?" that may only generate one comment. In contrast, another student may post deeper questions that lead to a larger discussion (several comments). While just analysing the number of posts may favour the first student, pagerank looks at interaction generated by the posts to better characterize engagement. As will later be shown in Figure 2, a majority of students who did post only still have a very low pagerank. Likely these students posted only once and their posts received no or few comments. Whereas, students who are outliers likely were not only posting frequently, but creating posts that other students commented on frequently. One limitation to this analysis is that it does fail to account for the relevance of posts (e.g. a post on a topic unrelated to the course that receives high engagement). However, since this analysis is not looking at individual posts but the overall engagement with posts created by individual students, we assumed that the effect of irrelevant posts is negligible.

Performance is characterized by final course grade on a 4.0 scale where a 4.0 corresponds to an A (90%-100%). Control variables will include GPA prior to the course and performance in the prerequisite course (statics).

None of the demographic variables in the data were missing for any of the student analysed in this study. Co-occurring missingness was examined and no patterns existed in missingness among the variables examined. Multiple imputation using R's MICE package was completed before analysing the data (van Buuren & Groothuis-Oudshoorn, 2011).

This paper hypothesizes that a significant mediating effect exists for demographics (gender identity, race, and international status) on engagement which in turn affects performance as shown in Figure 1. Prior work has established a relationship between demographics and engagement in the online discussion forum (Duan et al., 2018) reflected in Figure 1 as relationship A. Literature has established a relationship between engagement in an online discussion forum and performance (Davies & Graff, 2005; Hrastinski, 2008) reflected as relationship C in the figure. Since engagement correlates to performance and demographics relate to engagement, this paper proposes a pathway AB through which demographics act as a mediating variable for engagement thus impacting overall performance.

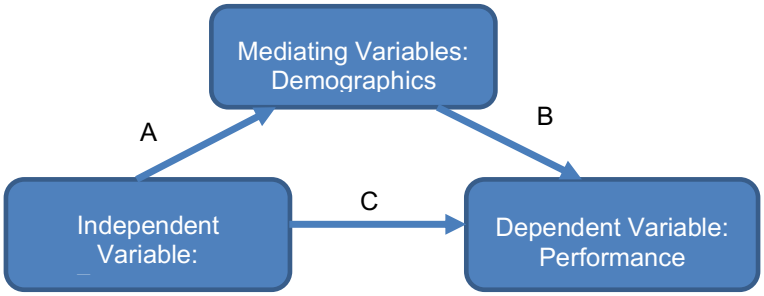

Figure 1: Conceptual Model – Mediating Effect

To investigate the hypothesized mediation effect, we used *mediate* in R's *mediation* package (Tingley et al., 2014) as well as bootstrapping to test if a significant mediating relationship exists. This analysis uses relationship A and C to test if relationship B exists and is significant. To investigate the hypothesized moderation effect, we created three models; Model 1 without demographic factors, Model 2 with demographic factors and Model 3 with interaction terms.

Descriptive Statistics

Table 1. Summary Statistics

	Mean	Standard Deviation	Min-Max
Final Grade	2.6	0.9	0.0-4.0
PreReq* Grade	3.1	0.8	0.7-4.0
GPA	3.4	0.4	0.0-4.0
Pagerank	0.0011	0.0031	0.0000-0.0384

	Men	Women
Gender	1518	352

	White	URM	Asian American	International
Race/Ethnicity	1146	201	154	369

*PreReq = Prerequisite course (statics)

From the summary statistics, it is important to note that pagerank does not have a normal distribution. Most students never posted on the discussion forum and thus have a pagerank of zero meaning that the variable is zero-inflated. The median values of pagerank are the same for each demographic category (median = 0) as a majority of students in all

demographic categories did not engage with the discussion forum. Figure 2 shows a violin plot of pagerank with zeros removed revealing that students of different races/international statuses did vary in pagerank. For white students, the overall range but the number of students slowly decreases for higher levels of engagement. Compared to White students, International students have a greater percentage of students at higher values up to pagerank of 0.01 and have higher outlying values than the white student. Additionally, the range of pagerank values for Asian American students is lower than other groups meaning that fewer outliers exist. Prior analyses gave a very different view finding that Asian American students were more likely to participate in the discussion forum when measured through the binary of whether they participated at all in the forum or not. Within this analysis, their data shows a bimodal distribution, but unlike other groups they have no students above a pagerank of 0.01. Thus, building on the prior analysis, this paper shows that while Asian American students were more likely in have at least one post, they engaged in the discussion forum differently than White, URM, and International students.

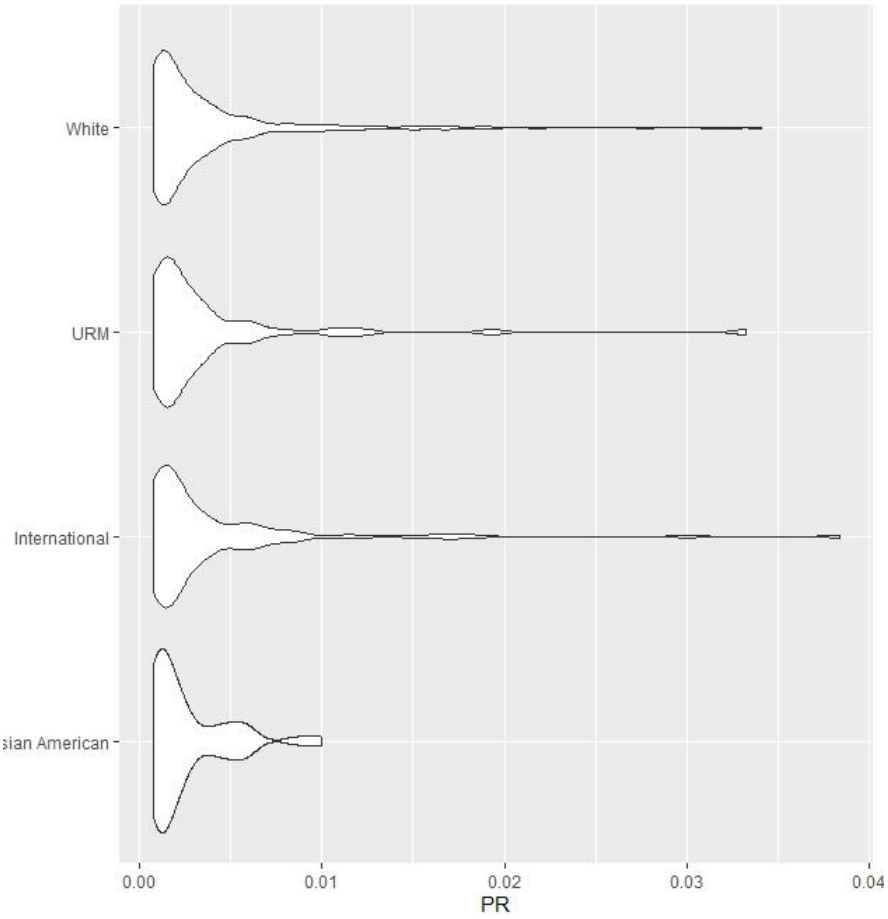

Figure 2. A violin plot of pagerank (with zeros removed) for race/international status

Bivariate analyses were completed for each of the variables. Table 2 shows Spearman correlation tables for numerical variables as several variables violate the assumptions required to do Pearson correlations including normality of variables. Table 3 shows the Kruskal Wallis test for categorical variables used to compare groups within demographics as it is a non-parametric method that does not require equal group sizes and can compare more

than 2 groups at once (McKight & Najab, 2010). A significant Kruskal Wallis test indicates that at least one group is significantly different.

Table 2: Spearman Correlation

	Final Grade	Pre-Req Grade	Prior GPA	Pagerank
Final Grade	1			
Pre-Req Grade	0.6603	1		
Prior GPA	0.7061	0.7369	1	
Pagerank	0.1723	0.1456	0.1534	1

Table 3. Kruskal Wallis tests statistics. P-values are in parentheses

	Final Grade	Pre-Req Grade	Prior GPA	Pagerank
Gender Identity	X^2= 13.429 (p < .001)	X^2= 16.999 (p < .001)	X^2= 0.7906 (0.374)	X^2= 5.800 (0.016)
Race/Ethnicity	X^2= 6.895 (0.075)	X^2= 11.225 (0.011)	X^2= 17.240 (p < .001)	X^2= 3.106 (0.376)

Results and Analysis

For both mediation models, no significant mediating effect was found (relationship B in Figure 1). Testing for relationship A, an ordinal and logit regression models for race/international status and gender identity respectively showed no significant relationship between demographics and pagerank. Therefore, no mediation effect was found. Nevertheless, it is important to point out that these models may not accurately deal with the zero-inflated pagerank variable due to a majority of the students choosing not to participate in the online discussion forum.

Table 4. Three Regression Models

	Model 1: Controls	Model 2: Demographics Added	Model 3: Moderation Analysis
Pagerank (PR)	12.036 (p = .009)	12.056 (p = .009)	14.228 (p = .019)
PreReq Grade	0.349 (p < .001)	0.330 (p < .001)	0.328 (p < .001)
GPA	1.022 (p < .001)	1.053 (p < .001)	1.054 (p < .001)
Women		-0.107 (p =.004)	-0.130 (p = .001)

Race/International Status			
URM		-0.014 (p = .767)	0.012 (p = .806)
Asian American		-0.088 (p = .096)	-0.080 (p = .164)
International		-0.127 (p = .001)	-0.116 (p = .003)
Interaction Terms			
PR: Women			22.094 (p = .099)
PR: URM			-27.443 (p =.086)
PR: Asian American			-9.215 (p =.767)
PR: International			-10.233 (p = .349)
AIC	**3500**	**3488**	**3491.4**

For the moderation effect, Model 3 shows how the addition of interaction terms caused the overall effect of engagement on performance to increase from 12.056 to 14.228 while all the other terms between the two models (Demographics and Interaction models) remained similar. As a reminder, this coefficient would be multiplied by the pagerank value for the student (mean = 0.0011). All interaction terms in Model 3 show how the relationship between engagement and performance changes for different demographics. For example, women students would have a 22.094 + 14.228 coefficient for pagerank. For a 0.001 increase in pagerank (similar to the mean value of pagerank), women would on average correlate to a 0.036 increase in performance (final course grade on a 4.0 scale). For the student who achieved the highest pagerank (pagerank = 0.0384), this would result in a 1.382 increase in performance. However, the model also shows that white men (the reference category of our model) has a higher pagerank coefficient (pagerank coefficient= 14.228) than the average student (pagerank coefficient =12.056). In other words, compared with the average student, a 0.001 increase in pagerank would on average correlate to a 0.002 higher final course grade for white men. While interaction terms were not found to be significant to conclude the existence of a moderation effect, this change between the three models does show however a relationship between demographics, online engagement, and performance in the course.

Conclusions and Limitations

This paper showed the existence of a relationship between students' demographic factors, their online engagement in a discussion forum and their course performance. The interaction terms were not significant for moderation and mediation. The differences in coefficients between models as discussed above do show that white men compared with the average student have higher pagerank coefficients in the analysis. This suggests some connection between students' demographic factors, their online engagement in a discussion forum and their course performance. The main limitation of our analysis is the operationalization of variables also presents issues specifically for engagement. Engagement could be operationalized by examining additional offline variables, such as course attendance, which was not gathered in this dataset but has previously been correlated with course grades (Ulmer, 2020) or by examining online variables such as clicks within the online course environment (not fully recorded in this dataset). This paper focuses on online engagement specifically in the discussion forum as it is a key blended (online) component that also allows for collaboration amongst students (Duan et al., 2018), which was also recorded within the dataset.

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