The Impact of Instructor Experience on Student Success for a Blended, Undergraduate Engineering Class

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Abstract

The growing need for STEM expertise has spawned significant research related to student retention and matriculation with these important disciplines. Recently, this research focus has shifted toward gateway, sophomore-level courses, due to their prominence in the student's technical formation (i.e. it is the level at which the students first enter their discipline). This work seeks to meaningfully add to the growing amount of literature in this research area by investigating how instructor experience in an Active, Blended, and Collaborative (ABC) learning environment impacts student success at the tertiary level. The work demonstrates that instructors educating within this learning environment experience similar learning curves as new K-12 teachers, with maximum effectiveness being achieved after approximately three semesters.

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Introduction

With the growing number of science, technology, engineering, and math (STEM) jobs in the United States, there is increased attention on recruiting and retaining students in STEM disciplines (National Science Board, 2016; Geisinger & Raman, 2013; Main, Mumford, & Ohland, 2015; Ohland et al., 2008). Studies have shown that students leave engineering for a variety of reasons including low course grades and lack of engagement in an engineering community (Geisinger & Raman, 2013; Main et al., 2015). Other studies have found that a teacher's professional experience influences student success (including final grade; e.g., Henry, Fortner, & Bastian, 2012; Carrell & West, 2010) and that active (Freeman et al., 2014), blended (Bowen, Chingos, Lack, & Nygren, 2012), and collaborative (Jeong & Chi, 2006) pedagogical techniques increase student learning and engagement. This work operates at the intersection of the aforementioned research areas and investigates how teacher experience in an active, blended, and collaborative (ABC) learning environment impacts student success in a gateway, sophomore-level engineering class on dynamics. The possibility that an aligned ABC environment may shorten or eliminate the learning curve for new instructors motivates this research.

At Purdue University, an ABC learning environment, called *Freeform*, has been used in an undergraduate dynamics and mechanical vibrations course, ME 274 (or "Dynamics"), in mechanical engineering since 2008. *Freeform* encourages instructors to use active learning techniques (but does not dictate pedagogical choices) and supports instructional decisions with a custom-written textbook/workbook (a "lecturebook"), an extensive online video library of worked example problems and demonstrations, and an online discussion forum (Rhoads, Nauman, Holloway, & Krousgrill, 2014). Since *Freeform*'s inception, the rate at which students earned a final grade of D, F, or W (the DFW rate) in Dynamics has dropped from over 20% to approximately 10%, Figure 1. Because Dynamics is a required class for the majority of the students who take the course, the DFW rate is an indicator of a student's persistence toward degree completion.

Prior research suggested that the maturation of the *Freeform* environment over time may have contributed to the reduction of DFWs (DeBoer, Stites, et al., 2016). The results from DeBoer et al. also illustrated no difference in student outcomes for instructors who developed *Freeform* and those who did not. This paper, however, explores the possibility that the instructor type and the maturation of *Freeform* over time may be confounded. Therefore, an instructor's teaching experience in the *Freeform* environment likely captures the effects of instructor and time together. Instructors of Dynamics inherently gained more experience with *Freeform* over time, as shown in Figure 2, and research on K-12 education suggest that students' academic success improves as a new teacher gains experience (Henry et al., 2012). The change in teacher effectiveness for new instructors at the tertiary level, however, has not been well studied. Similarly, research looking at how student success is impacted by instructor experience with a specific course (such as a new or transformed course) regardless of prior teaching experience could not be found. Therefore, this work believed to be a valuable contribution to the body of literature regarding teacher effectiveness in a transformed course with an ABC learning environment at the post-secondary level.

Theoretical Framework

Much of the literature linking teacher experience and effectiveness focuses on K-12 instruction. Many studies suggest that the impact of teacher experience on student performance is strongest in the first three to five years of service, after which the returns on added years of service diminish (Rice, 2013; Rivkin, Hanushek, & Kain, 2005; Henry et al., 2012; Darling-Hammond, 2000). Henry et al. (2012) and Rice (2013) further specified that for science and math teachers, the most significant increase in value added by teachers occurs during their first year of teaching and levels off during their fourth and fifth year of experience. The body of literature examining teacher effectiveness at the post-secondary level is limited. Carrell and West (2010) found that students earned higher scores (controlling for grading differences between instructors) in a contemporaneous class with a less-experienced professor, but students with more-experienced professors performed better in related, follow-up classes. Therefore, Carrell and West's results suggest that students in Dynamics (the contemporaneous course) with less-experienced instructors may earn higher scores, which is contrary to prior findings in the K-12 context.

The minimal literature on teacher experience in higher education illustrates the need for the current study. However, unlike the K-12 studies, this work concerns teacher effectiveness as a function of prior experience teaching Dynamics within the *Freeform* environment rather than developing a teacher-effectiveness curve based on overall teaching experience. The justification of the approach is based on veteran instructors of Dynamics stating that teaching Dynamics within the *Freeform* environment is "developing a new course" (DeBoer, Gerschutz, et al., 2016). Therefore, instructors of Dynamics may experience a teaching-effectiveness curve similar to that of early-career K-12 teachers, or, as a competing hypothesis, the ABC resources of *Freeform* may minimize the impact of an instructor's prior experience and normalize the effectiveness of all instructors. **Therefore, the research question guiding this work is to what extent does an instructor's experience teaching in the *Freeform* environment impact student performance in Dynamics?**

Methods

Participants

The sampling frame for this study included students enrolled in spring-semester sections of Dynamics at Purdue University from 2009 (the first spring semester using a complete implementation of *Freeform*) to 2015. The spring offering of Dynamics is the semester in which students traditionally take the course, if they follow the most common plan of study. Twenty sections of Dynamics (2360 students; 1966 male, 375 female, 19 unknown) were taught by seven different instructors between 2009-2015. The two instructors that developed *Freeform* taught 10 sections (1273 students), and instructors that did not develop *Freeform* taught the other 10 sections (1087 students). The Dynamics students were predominately white ($n = 1579$) or "international" ($n = 437$) in ethnicity. Except for three students, all students that reported as "international" for ethnicity were also classified as international (or foreign) for residency, so this study assumes "international" as both an ethnicity and a residency status.

Measures

Prior research on retention in higher education (Kuh, Kinzie, Buckley, Bridges, & Hayek, 2006; French, Immekus, & Oakes, 2005) and student performance in dynamics (Huang & Fang, 2013) informed the variable selection for this analysis. The measures of interest were organized into three categories, as shown in Table 1.

The analysis used a first- and second-order instructor-experience variable to model any nonlinear effects that variable might have on student performance. Also, the overall GPA was scaled by three to be on a 12.0 scale so that a one unit increase in GPA on a 12.0 scale corresponded to a 0.33 unit increase in GPA on 4.0 scale (approximately a change in a +/- letter grade) so as to make the odds ratio from the logistic regression model more meaningful. Similarly, credits accumulated were divided by 15 so that a one unit increase corresponded to 15 additional credits earned, or approximately one semester's worth of credits. The Statics grade was included because it is the only required prerequisite for Dynamics. Multiple imputation ($m = 5$) was used to estimate missing data (Little & Rubin, 2002; Rubin, 1987). The measure of teacher effectiveness used in this work is the probability of a given student earning a DFW, so the lower the probability of a DFW, the more effective an instructor is considered to be.

Analysis

Because DFW rate can be considered to be an indicator of student persistence in their engineering program, a logistic regression model was used to identify statistically significant factors influencing the predicted probability of a student earning a DFW given teacher experience (EXPER), academic (ACAD), and demographic (DEMOG) values:

$$P(Y = DFW|X = x) = \frac{e^{\beta_0+\beta_1 EXPER+\beta_2 ACAD+\beta_3 DEMOG}}{1 + e^{\beta_0+\beta_1 EXPER+\beta_2 ACAD+\beta_3 DEMOG}}. \quad (1)$$

Teacher effectiveness was illustrated by plotting the probability of a given student earning a DFW, using Equation 1, for varying levels of instructor experience in *Freeform*. The probability is based on a white, male student with average values for all other variables.

Results

The odds ratios (ORs) and associated *p*-values for each of the variables in the logistic regression model are shown in Table 2. The statistical significance of the first- and second-order terms for instructor experience implies that a statistically significant nonlinear relationship exists between student success and instructor experience in *Freeform*. Figure 3 illustrates that the estimated probability of earning a DFW for a given student decreases nonlinearly with each semester of prior experience an instructor has teaching in the *Freeform* environment. In general, the ORs from Table 2 indicate that more instructor experience and a higher GPA reduce the probability of earning a DFW (ORs < 1). However, the benefit of additional instructor experience decreases as experience increases (OR of higher-order term $>$ 1). Additionally, more accumulated credits, lower statics grades, international residency, and a major other than mechanical engineering increase the probability of earning a DFW.

Discussion and Conclusion

The trend of increased student success (and decreased probability for a DFW) as an instructor gains experience in the *Freeform* environment resembles the teacher-effectiveness curves commonly seen in K-12 research. Similar to the impact of a K-12 teacher's first year, the first semester of experience in *Freeform* seems to have the most effect on student performance. However, the increased benefit of added experience diminishes significantly after the third instance of teaching Dynamics within the *Freeform* environment, a trend that parallels the results for new K-12 science and math teachers (Henry et al., 2012).

The slight increase in the probability of a DFW for instructors with six and seven semesters of experience could indicate that the logistic repression model is missing important factors, e.g., class size or if a student is repeating the course. Future work will explore these variables as well as the effect of prior teaching experience outside of the *Freeform* environment on student success. Finally, students from the fall-semester offerings of the course will be incorporated into the prediction model. In conclusion, the results of this study do not support the hypothesis that *Freeform* may shorten or eliminate the learning curve of instructor effectiveness, but they do show that post-secondary instructors teaching in a new ABC learning environment experience similar learning curves as new K-12 teachers.

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Role of Researchers

The research team for this study includes graduate research assistants, faculty members, and professionals from Purdue University's School of Engineering Education and School of Mechanical Engineering. Concerted efforts have been taken to analyze and report results in an unbiased and objective manner.

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Table 1

Variables Used in the Model to Predict the Probability of a Student Earning DFW

Variable	Illustrative Descriptive Information	Unit
Teacher Experience		
Instructor Experience in *Freeform*	Min = 0; Max = 7	# semesters
Academic Information		
Prior GPA	$\bar{X}$ = 3.2 (S = 0.52)	4.0 scale
Statics Grade	$\tilde{X}$ = 3.0 (IQR = 1.7)	4.0 scale
Accumulated Credits	$\bar{X}$ = 67 (S = 17)	credit hours
Major	79% Mechanical Engineering	
Demographics		
Ethnicity[a]	67% White	
	6% Asian	
	1% Black or African American	
	3% Hispanic/Latino	
	19% “International”	
	1% Other	
	4% Missing Data	
Gender	83% Male	
	16% Female	
	<1% Not Specified	

[a] Note that the percentages of ethnicity do not add up to 100% because of numerical rounding.

Table 2
Odds Ratios

Variable	Odds Ratio	*p*-values
Teacher Experience		
Instructor Experience in *Freeform*	0.595	<0.001
(Instructor Experience in *Freeform*)^2	1.055	0.001
Academic Information		
Prior GPA (on 12.0 scale)	0.407	<0.001
Statics Grade: "F"	0.000	0.973
Statics Grade: "D-"	0.509	0.633
Statics Grade: "D"	4.890	0.003
Statics Grade: "D+"	2.949	0.013
Statics Grade: "C-"	2.287	0.013
Statics Grade: "C"	2.284	0.001
Statics Grade: "C+"	1.255	0.380
Statics Grade: "B-"	1.163	0.626
Statics Grade: "B"	Reference	
Statics Grade: "B+"	0.647	0.185
Statics Grade: "A-"	0..669	0.410
Statics Grade: "A"	0.673	0.324
Accumulated Credits (per 15 credit hours)	1.176	0.012
Major: Mechanical Engineering	Reference	
Major: Non-Mechanical Engineering	1.756	0.001
Demographics		
Domestic Student, Ethnicity: White	Reference	
Domestic Student, Ethnicity: Asian	1.226	0.514
Domestic Student, Ethnicity: Black or African American	1.237	0.692
Domestic Student, Ethnicity: Hispanic/Latino	1.145	0.745
Domestic Student, Ethnicity: Other	0.390	0.254
International Student, Ethnicity: "International"	1.954	0.003
Gender: Male	Reference	
Gender: Female	1.021	0.918
(Intercept)	267.611	<0.001

Note: *p*-values of 0.05 or less were considered statistically significant. The odds of a student earning a DFW was defined as the probability of a student earning a DFW divided by the probability of a student *not* earning a DFW. An odds ratio (OR) can be conceptualized as the factor by which the odds of a student earning a DFW changes for a one unit increase in one variable while all other variables remain constant. Therefore, an OR of less than one indicates that a variable decreases a student's odds of earning a DFW.

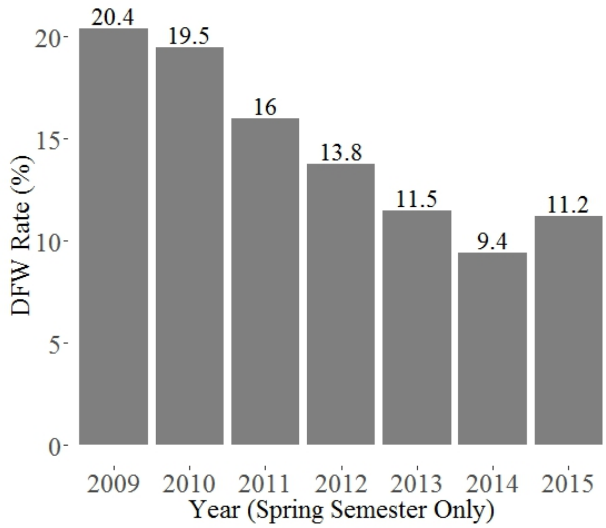

Figure 1. Since the inception of *Freeform*, the DFW rate in Dynamics has significantly decreased.

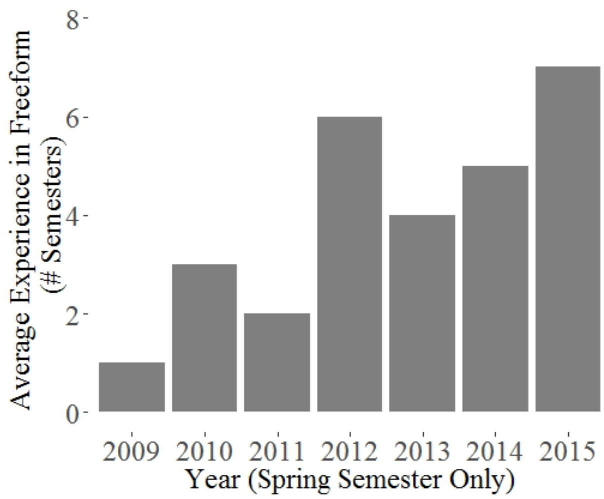

Figure 2. Because *Freeform* is institutionalized at Purdue University for Dynamics, instructors implicitly gain experience teaching in *Freeform* over time.

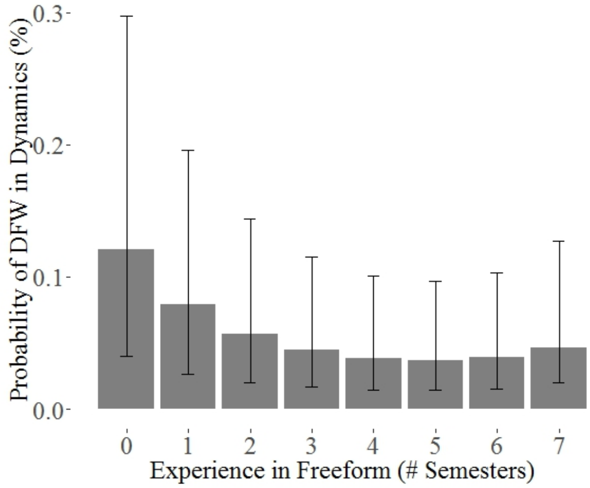

Figure 3. The probability of students earning a DFW decreases as an instructor gains experience with *Freeform*. The error bars represent 95% confidence intervals.