A study of student entry behaviors and directed self-placement in an introduction to circuit analysis course

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***Abstract*— In this work, which is intended to be a Work in Progress Paper in the Research Category, the results of an extensive study which used three-factor and two-factor linear regression models based on prior grade point average, grades in a pre-requisite physics course, and class size is presented. In both models prior GPA was the most significant factor in predicting student success, followed by the grade in a pre-requisite physics course. Even though class size was not a significant factor, removing it from the analysis lowered the R^2 values. The study analyzed 39 sections of an introduction to circuit analysis course from fall 2013 to spring 2018 and examined whether previously published novel treatments or class size (or both) were the reason for increased pass rates. It was found that there were no significant entry behavior differences between those students who enrolled in a traditional course vs. the students enrolled in a directed self-placement course. It was found that the sections that used the directed self-placement policy tended to outperform sections that did not use this policy.**

***Index Terms*— Circuits and systems, student success, placement exam, MyOpenMath, entry behaviors, prior GPA, class size, prerequisites**

I. Introduction

Decreasing the DFW rate (percentage of students who earn a D, F or W in a course) has been a priority for the researchers' university system for many years due to the projected need for engineers, and the state tuition subsidy. In addition, it costs students approximately $40k for each semester graduation is delayed in extra tuition, housing costs, and lost wages [1].

A previous study showed that a novel stay/add/drop policy[1] (which was effectively a directed self-placement policy) was the only intervention that was shown to decrease the DFW rate [1]. A further study was conducted which analyzed student entry behaviors such as prior GPA, and grade in a pre-requisite physics course to explore if the stay/add/drop policy was the cause for the decreased DFW rate [2]. Given that this previous study [2] found that a statistically significant model could be found with just prior GPA and the grade in a pre-requisite physics course, it was decided to use this model along with class size to determine if student entry behaviors had changed, and if the sections with the stay/add/drop policy outperformed the course sections that did not have this policy.

While the stay/add/drop policy did seem to be effective at lowering the DFW rate, managing it was becoming difficult because sometimes there were confrontations with students being dropped and some students were made to feel unwelcome. In reality, very few students were dropped by the instructor because most students dropped on their own. Given that the policy might seem unwelcoming, and most students self-placed, the policy was changed from a stay/add/drop policy to a directed self-placement policy. All sections that used the old stay/add/drop policy were identified as directed self-placement. The directed self-placement policy consists of informing the students that they need to earn 90% on their homework assignments to succeed in the class, and if they cannot achieve this, they can ask to be dropped from the course with no penalty after the sixth homework assignment. The extra effort required to implement this policy is justified because the directed self-placement policy seemed to be the only treatment that would successfully lower the DFW rate at the author's institution, despite previous work [3-9].

While there have been many studies looking at directed self-placement for first-year college composition courses [10-12], none seem to have been done for an Introduction to Circuit Analysis (ICA) course, or another engineering course. One study proposed using an exam as a directed self-placement activity for a junior level circuits and systems course [13], but no data was provided.

Faculty interested in decreasing DFW rates of engineering classes should find this work of value, as well as department chairs try to manage class size and student success.

II. Methodology

Student records were extracted for every section of the introduction to circuit analysis course from the fall of 2013

[1] Students had to earn a 90% on homework assignments before the drop date or they would be dropped from the course or not allowed to add the course.

until the spring of 2018 including summer. Each record contained the student's grade from the physics pre-requisite (PHY_GPA), the GPA prior to taking the introduction to circuit analysis course (P_GPA), the grade that was earned in the introduction to circuit analysis course (ICA_Grade), if the student was in a directed self-placement section or non-directed self-placement section, the number of students enrolled in the student's section (CS) and if the student was taking the introduction to circuit analysis course for the first time. The variable (factor) definitions can be seen in table 1. The analysis tool for the descriptive statics and the linear regressions were python pandas and OLS [14]

All students who were repeating the ICA course were removed from the analysis because it is more important to study first time pass rates. Also, all the students who took the pre-requisite physics course were eliminated from the study as the grade data was missing for transfer students. Removing these students reduced the number of student records to 1227. The descriptive statics for the whole population can be seen in table 2.

Table 1: Variable (factor) definitions

Term	Definition
PHY_GPA	The student's grade converted to a 4.0 scale in the pre-requisite physics course.
P_GPA	The student's GPA prior to taking the introduction to circuit analysis course. The priorIncludes grade forgiveness.
CS	The number of students enrolled in a section of the introduction to circuit analysis course.
ICA_Grade	The student's introduction to circuit analysis grade converted to a 4.0 scale.

Three-factor (PHY_GPA, P_GPA, and CS) and two-factor (PHY_GPA and P_GPA) linear regression analyses were performed on the 1227 student cohort to develop a function that would predict the final grade in the ICA course.

The sections were split into non-directed self-placement (744 students) and directed self-placement (483) groups and descriptive statics calculated which can be seen in tables 3 and 4. Then a three-factor (PHY_GPA, P_GPA, and CS) and two-factor (PHY_GPA and P_GPA) linear regression analyses were performed on the non-directed self-placement, and directed self-placement cohorts to explore differences between the non-directed self-placement, and directed self-placement.

Table 2: Descriptive Statistics for 1227 student cohort.

Item	Mean	Standard deviation	Minimum value	Maximum value
PHY_GPA	2.93	0.70	1.70	4.00
P_GPA	3.13	0.39	1.92	3.98
ICA_Grade	2.55	1.09	0.00	4.00
CS	70.28	17.76	10	103

Table 3: Descriptive Statistics for non-directed self-placement (744 students) cohort.

Item	Mean	Standard deviation	Minimum value	Maximum value
PHY_GPA	2.92	0.68	1.70	4.00
P_GPA	3.1	0.39	1.92	3.97
ICA_Grade	2.49	1.04	0.00	4.00
CS	71.0	21.0	10.0	103.0

Table 4: Descriptive Statistics for directed self-placement (483 students) cohort.

Item	Mean	Standard deviation	Minimum value	Maximum value
PHY_GPA	2.96	0.72	1.70	4.00
P_GPA	3.17	0.38	2.02	3.98
ICA_Grade	2.65	1.16	0.00	4.00
CS	69	11	42	83

III. Results and Discussion

Looking at means of the student entry behaviors such as prior GPA, and grade in a pre-requisite physics course of the whole cohort (table 1), for the non-directed self-placement cohort (table 2), and for the directed self-placement cohort (table 3), it can be seen that the entry behaviors of the students are indistinguishable. The fact the cohorts have indistinguishable entry behaviors, strongly suggests that the reduction of the DFW rates reported previously are not due to a change in the student population. While the final grade in the ICA course of the directed self-placement cohort may seem only slightly larger than that of the non-directed self-placement cohort, this can be explained that the non-directed self-placement cohort included the summer offering of the ICA courses which typically had small class sizes and were accelerated so that the summer students tended to perform better than non-summer students.

Table 5: Three-factor model parameters to predict final grade in ICA (1227 students, R^2=.262, significance less than 0.001)

Item	coef	std err	t	P>|t|
const	-1.7108	0.243	-7.047	Less than .001
PHY_GPA	0.1485	0.047	3.13	0.002
P_GPA	1.2766	0.086	14.89	Less than .001
CS	-0.0023	0.002	-1.511	0.131

Table 6: Non-directed self-placement three-factor model parameters to predict final grade in ICA (744 students, R^2=.309, significance less than 0.001)

Item	coef	std err	t	P>|t|
const	-2.0037	0.279	-7.183	Less than .001

PHY_GPA	0.1243	0.056	2.227	0.026
P_GPA	1.3597	0.098	13.832	Less than .001
CS	-0.0011	0.002	-0.759	0.448

Table 7: Directed self-placement three-factor model parameters to predict final grade in ICA (483 students R^2=.202, significance less than 0.001)

Item	coef	std err	t	P>|t|
const	-0.9396	0.481	-1.954	0.051
PHY_GPA	0.2	0.086	2.334	0.02
P_GPA	1.1189	0.164	6.829	Less than .001
CS	-0.0079	0.005	-1.729	0.084

All three models were statistically significant, with the model for the non-directed self-placement cohort having the highest R^2 value of 0.309, followed by the model of the complete group with an R^2 of 0.262, and the model of the directed self-placement cohort with the lowest R^2 of .202. The reason for the different R^2 values needs to be investigated further.

The most significant factor for the three-factor analysis for the whole population (Table 5) and the two cohorts (Tables 6 and 7) was prior GPA, followed by the grade in the pre-requisite physics course and then class size. The coefficients for PHY_GPA and P_GPA were both positive, and the coefficient for CS was negative as one would expect. The main difference between the cohorts is that ratio of the t-values of P_GPA and PHY_GPA was much more significant for the non-directed self-placement group than the directed self-placement group. This is most likely is due to a concurrent re-alignment of the pre-requisite physics and the ICA. The fact that Prior GPA was the most significant factor in predicting student success is supported by many researchers [15-27].

Given that the CS factor was not a significant factor of the three-factor model, a two-factor model that included PHY_GPA and P_GPA only was carried out the non-directed self-placement group, and the directed self-placement group. The results are statistically significant and can be seen in Tables 8, 9, and 10. P_GPA is still the most significant factor for both groups, and the PHY_GPA for the directed self-placement group is more significant than the non-directed self-placement group

Table 8: Non-directed self-placement two-factor model parameters to predict final grade in ICA (744 students, R^2=.308, significance less than 0.001)

Item	coef	std err	t	P>|t|
const	-2.0871	0.256	-8.144	Less than .001
PHY_GPA	0.1247	0.056	2.234	0.026
P_GPA	1.36	0.098	13.839	Less than .001

Table 9: Directed self-placement two-factor model parameters to predict final grade in ICA (483 students R^2=.197, significance less than 0.001)

Item	coef	std err	t	P>|t|
const	-1.3811	0.408	-3.382	0.001
PHY_GPA	0.2079	0.086	2.425	0.016
P_GPA	1.0798	0.163	6.64	Less than .001

Figure 1 shows the means of the GPA of the course (ICA_grade) for each section of the non-directed self-placement group (blue circles) and the means of each section of the directed self-placement group (red circles) plotted against the function of the three-factor model (F_3FM) of the complete group (Table 5). The F_3FM was plotted against itself so that one could see if a section did better than the model predicted or worse than the model predicted. One can see that nine sections of the directed self-placement cohort had a higher mean of the final course grade than the model predicted with fives sections below what the model predicted. This result can be compared to the non-directed self-placement cohort which had ten sections higher than the model prediction and 15 sections lower than the model prediction. While the most likely reason the directed self-placement sections tended to outperform the non-directed self-placement sections was due to the new policy, it could also be that underperforming instructors (based on student evaluations, not this work) were let go sooner than in the past.

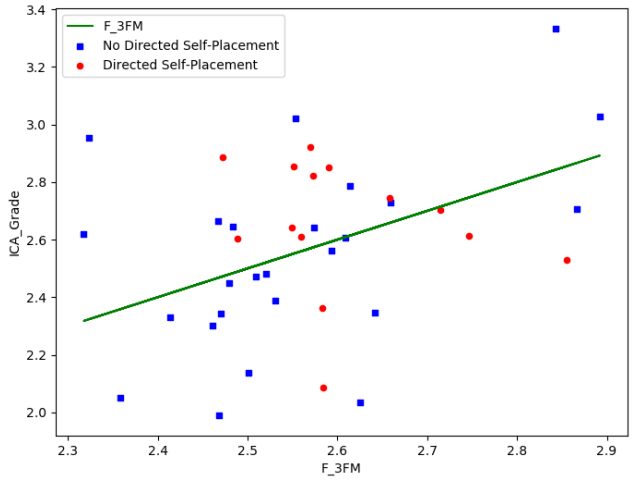

Figure 1: Mean ICA_Grade vs. F_3FM

Figure 2 shows the mean of the GPA of the course (ICA_grade) for each section of the non-directed self-placement group (blue circles) and the mean of each section of the directed self-placement group (red circles) plotted against the class size of each section. There is quite a large variability in the mean of the final course grade for a given class size, especially for small class sizes. This could be

due to the fact some instructors enforce differential equations as a pre-requisite in the summer, even though it is usually a co-requisite because it was felt that these two courses should not be taken at the same time due to the accelerated nature of summer courses. In addition there could have been some self-placement because some summer sections followed the "impedance first model" [1] which starts with impedance rather than DC circuits. Since there was no officially directed self-placement policy for these sections, they were put into the non-directed self-placement cohort.

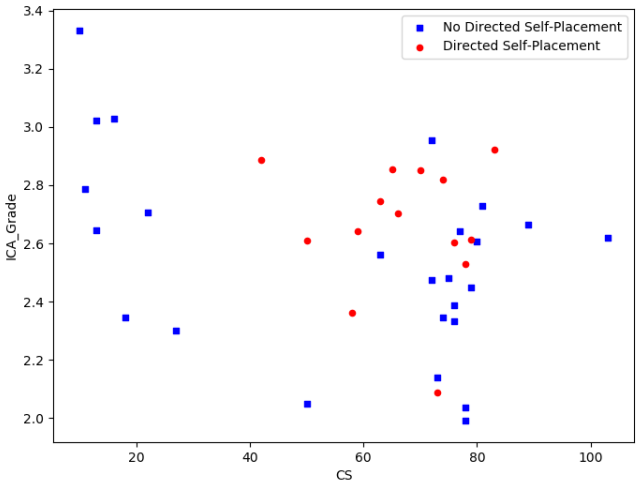

Figure 2: Mean ICA_Grade vs. class size.

At this time the fall 2018 and spring 2019 data is not available but should be at the end of May. Looking at table 10 it appears that switching to a more compassionate directed self-placement policy has not resulted in any significant change in student outcomes.

Table 10: The class average on midterm 1 for spring 2019 by section.

Section	CS	Midterm 1 Average
1	62	81.5
2	65	73
3	65	72

IV. Conclusions

There seems to be no significant difference between the groups in terms of entry behaviors as measured by the prior GPA and grade in the physics course. This is important because, at the authors' institution, the department has become more selective as the desire of students to enroll in EE outstrips the capacity. This impaction has led to a higher admission standard for first-time freshman, yet the means of PHY_GPA and P_GPA by the time students take the ICA course (~three semesters) are the same. The non-directed self-placement sections were from fall 2013 until fall 2015, and the directed self-placement sections were offered started in the spring of 2016. While we may seem to have "better" First Time Freshman (FTF), it does not seem to impact what is going on two years later. A study of the transfer students should shed more light on this, as the admissions requirements for transfers have gone up as well.

The t-value ratios of the P_GPA and PHY_GPA were between two and six, and the coefficient ratios of the P_GPA and PHY_GPA were between five and ten which shows that PHY_GPA is not a strong predictor of student success, therefor the policy of allowing a C- or better in the pre-requisite physics course (instead of C or better) should be continued or the catalog changed to allow C- or better.

Even though prior GPA is more critical the physics course grade, there might not be much that can be done with the information to help students. Having a policy that uses a cutoff prior GPA to allow a pre-requisite exception, seems difficult to administer, or maybe considered unfair to students. It would be better to allow all students with a C- or better to take the course and offer services to help all students succeed such as an ICA workshop.

Given that class size was found not to be significant in predicting student success, there is no reason to keep underperforming instructors for the reason of improving student success. Even though class size was not a significant factor in predicting student success, large class sizes are a workload issue. The instructors were able to manage the workload due to large class sizes by utilizing automatically graded online homework (MyOpenMath) [28-32], and a well-developed canvas shell with extensive online materials that included video instruction on common issues in teaching the course.

It is not recommended to use these linear regression models in the faculty retention process because it would pit instructors against each other.

While previous work on an ICA course did not show a benefit to using the flipped classroom model, it might be worth revising the technique now that the directed self-placement policy has shown to improve student success [33].

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