A pilot study of a directed self-placement exam and a workshop designed to improve student learning outcomes in a junior level circuits and signals course

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Abstract— **In this work, which is intended to be a Work in Progress Paper in the Research Category, a pilot study of a directed self-placement exam and a workshop designed to lower the DFW rate (% of students who earn a D, F, or W) is presented. Linear regression models that included the directed self-placement exam score, differential equations grade, introduction to circuit analysis grade, and prior GPA were created, and the four-factor model, best three-factor model, best two-factor model, and the individual factor models are presented. The most cost-effective model in terms of significance (less than 0.001) and R^2 (0.48) values was a two-factor model that included the introduction to circuit analysis grade, and prior GPA. This suggests that the directed self-placement exam is not needed to predict student success in the author's circuits and systems course.**

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

I. Introduction

Historically the approved method to keep the DFW rate (percentage of students who earn a D, F or W in a course) low in this circuits and systems course was using a placement exam/workshop to enforce student entry behaviors [1]. Even though this prior study showed that increasing the rigor and applicability of the placement exam decreased the DFW for three semesters, the DFW rate jumped from 15% to 30-35% after the study was published. It was felt that while the students were passing the exam, they were not really reviewing the concepts needed for success because the question bank was getting stale, and students were just memorizing the answers. Given these reasons and the fact that only two other universities in the United States have junior level placement exams [2-3] it was felt that the placement exam should be changed from a screening exam to a directed self-placement exam and that offering a workshop [4-6] to help the students meet the learning objectives of the circuits and systems course would decrease DFW rate. Ultimately the research question is: "What are the minim number of factors needed to predict student success in a circuits and systems class?" This information can then be used to decide to keep using the directed self –placement exam and set the minimum grades in the pre-requisite circuits analysis and differential equation courses students need to be able to enroll in the junior level circuits and systems course. This approach seems more in line with current research on improving student success [8-18].

The topics covered in the circuit and systems course were:

1. Analysis and synthesis arbitrary functions with step and ramp functions
2. Time domain and s-domain convolution
3. Creating asymptotic Bode plots and using bode plots for system identification
4. Low, high, band and notch filters synthesized with cascaded, parallel and state space methods
5. Gain band with (GBW) limitations of OPAMPs and how the GBW limit affects gain stages, filters and "ringing" of buffer output stages
6. Modeling spring mass damper systems as LRC circuits
7. System stability
8. Fourier expansion and transform with application toward pulse width modulated digital to analog converters.

The course uses elements from the three learning theories: Behaviorism [19], Cognitivism [20], and Constructivism [21]. In line with behaviorism, there are opportunities for extra credit, automatically graded homework assignments are used to provide immediate feedback before the first midterm [22-24], and homework assignments are changed periodically from semester to semester. Also in keeping with behaviorist theory, the course rules are specified in detail. For example The course has two midterms (25% each) and a final exam (35%) and homework (15% of the total grade). The final exam is broken up into three parts. The first two parts are based on midterms one and two, and the third part of the final exam was based on the material coved after the second midterm. If a student scores higher on the midterm one portion of the final exam, it replaces the original midterm 1 grade. The same policy is applied to the midterm two grade as well. The original midterm one and two grades do not replace the midterm one and two grades of the final exam.

In line with Cognitivism, the lecture and the workshop use analogies, case studies, and analogies so that students can internalize knowledge.

The directed self-placement exam was designed to control prior knowledge in accordance with Constructivism. This is based on the idea that students cannot create new knowledge or solve problems without prior knowledge. Interestingly, the exam itself is a drill/rote type exercise more in line with behaviorism.

II. Methodology

Preliminary activities for the workshop were planned based on the results of a survey conducted in the fall of 2018 of students of who had earned an 80% or higher on the first midterm of the circuits and systems course. What most students wanted to see in a workshop was problem-solving and practice midterm solutions. Another top-rated activity was for the students to create their own exam problems.

The workshop that was piloted during the spring 2019 semester met once a week for approximately two hours. The students (five total) self-selected to enroll in the workshop. Student participation might have been higher if it were offered with a greater selection of meeting times. The students who did enroll in the workshop wanted to see problem-solving, homework help, and the ability to ask off-topic questions, which were usually questions about pre-requisite knowledge. Sometimes the instructor would let the students work in small self-organized groups. To earn a CR grade in the workshop, students needed to participate in 80% of the activities. With such a small group of students enrolled in the workshop, it did not seem meaningful to make comparisons between those enrolled in the workshop and those that were not.

Given that comparing the student performance based on those who enrolled in the workshop to those who did not, would not generate statistically significant results, a statistical study on entry behaviors was conducted to see the effect of the directed self-placement exam would be in comparison with traditional factors such as grades in the pre-requisite courses and prior GPA. This study was conducted with a cohort consisting of 54 junior electrical engineering students who had earned a C or better in the pre-requisite courses, and who had taken the directed self-placement exam. The students in this cohort were enrolled in the spring 2019 semester offering of the circuits and systems course for the first time.

For each student, the score on the directed-self placement exam (DSPE_GPA), differential equations grade (DiffQ_GPA), introduction to circuit analysis grade (ICA_GPA), and prior GPA (P_GPA), were gathered and converted to a 4.0 GPA scale. A linear regression [7] four-factor model to predict the midterm one GPA, (the score of the midterm grade scaled to 4.0) was created using DSPE_GPA, DiffQ_GPA, ICA_GPA, and P_GPA. Then the best three-factor model was found by conducting a linear regression analysis on all the possible three-factor models. This was followed by performing a linear regression analysis on all the possible two-factor models. Finally, one-factor models were created for each variable. The factor definitions can be found in table 1.

Table 1: Variable (factors) definitions

Term	Definition
Midterm_GPA	The student's midterm one score scaled to a 4.0 scale.
DSPE_GPA	The student's score of the directed self-placement exam scaled to a 4.0 scale.
DiffQ_GPA	The student's differential equations grade converted to a 4.0 scale.
ICA_GPA	The student's introduction to circuit analysis grade converted to a 4.0 scale.
P_GPA	The student's prior grade point average in all course work at the author's institution and transfer work with grade forgiveness.

The directed self-placement exam was given to two groups of students. One group consisted of students enrolled in a workshop designed to help them pass the directed self-placement exam, and the other group included of those non-enrolled in this workshop. The average of the students enrolled in the exam preparation workshop (not the pilot workshop) was 81% with 74% achieving a score of 80% or greater, while the average of the students not enrolled in the workshop was 72% with 49% earning a score of 80% or higher. The old requirement was that students had to earn an 80% or higher to allowed to register for the circuits and systems course.

III. Results and Discussion

The descriptive statics for the 54 student cohort can be seen in table 2. The mean of the midterm grades was 3.1, although this drops to 2.7 when first-time students and repeating students in the class are included. The students who were not included were either repeating the course or did not take the midterm. The means and standard deviations for midterm 1, directed self-placement exam grade, differential equations grade, and introduction to circuit analyses grade seem to track closely, while the prior GPA is higher and the standard deviation is smaller by a factor of 2.

Table 2: Descriptive Statistics for 54 student cohort.

Item	Mean	Standard deviation	Minimum value	Maximum value
Midterm_GPA	3.05	0.70	1.40	4.00
DSPE_GPA	3.1	0.67	1.28	4.00
DiffQ_GPA	3.16	0.71	2.00	4.00
ICA_GPA	3.06	0.78	2.00	4.00
P_GPA	3.21	0.31	2.41	4.00

The results of the four-factor model linear regression can be seen in table 3. It can be seen that the grade in the introduction to circuit analysis course (ICA_GPA) has the highest t value (3.781), and lowest p-value (less than 0.001) suggesting that this is the most influential factor in predicting the midterm one grade. The $R^2 = 0.5$ and the significance were less than

0.001 for this model. The least significant factor is the grade on the directed self-placement exam (DSPE_GPA).

*Table 3: Four-factor model parameters used to predict the midterm 1 GPA. (ns-not significant p>0.05, * 0.05>p>.001, ** p<.001)*

	coef	std err	t	P>|t|
const	-0.7323	0.749	-0.977	ns
DSPE_GPA	0.0952	0.114	0.836	ns
DiffQ_GPA	0.1474	0.121	1.22	ns
ICA_GPA	0.4009	0.106	3.781	**
P_GPA	0.5586	0.263	2.123	*

The midterm GPA is plotted against the function of the four-factor model (F_4FM) in fig. 1. In this plot, three students did not pass the exam. The model predicts that all the students should pass. This suggests that the value of the y-intercept (const in table 3) should be more negative; however, these three students when compared to a population of 54 students, is not significant.

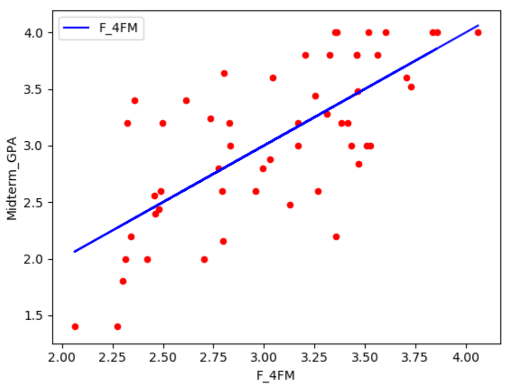

Fig. 1: The midterm GPA (red dots) plotted against the four-factor model (F_FFM), and the F_FFM plotted against the F_FFM (blue line).

A linear regression analysis was performed for all possible three-factor models, and the significance and R^2 values are summarized in table 4. The best model consisted of the differential equations grade, introduction to circuit analysis grade and prior GPA. The significance value is less than 0.001, and the R^2 is slightly lower than the four-factor model. The models that included the introduction to circuit analysis grade were had similar significance and R^2 values as the four-factor model. The model that did not include the introduction to circuit analysis grade had much higher values of significance and lower lower R^2 values.

Table 4: Significance and R^2 for each three-factor model. The best three-factor model is highlighted in green.

Elements	Significance	R^2
DiffQ_GPA, ICA_GPA, P_GPA	Less than 0.001	0.495
DSPE_GPA, ICA_GPA, P_GPA	Less than 0.001	0.487
DSPE_GPA, DiffQ_GPA, P_GPA	Less than 0.001	0.356
DSPE_GPA, DiffQ_GPA, ICA_GPA	Less than 0.001	0.456

Table 5 shows the coefficients, t values and p values of the best three-factor model. As in the four-factor model, the grade in the introduction to circuit analysis course seems to be the most influential factor. The next most significant factor is prior GPA followed by the grade in differential equations.

Table 5: Best three-factor model parameters to predict midterm 1 GPA. ***(ns-not significant p>0.05, * 0.05>p>.001, ** p<.001)***

	coef	std err	t	P>|t|
const	-0.6241	0.736	-0.848	ns
DiffQ_GPA	0.1471	0.12	1.222	ns
ICA_GPA	0.4211	0.103	4.092	**
P_GPA	0.5977	0.258	2.315	*

The midterm GPA is plotted against the function of the best three-factor model (F_B3FM) in fig. 2. This plot looks to be almost the same as the plot for the four-factor model suggesting that the extra effort involved in the proctoring the directed self-placement exam or using it in an analysis is not prudent.

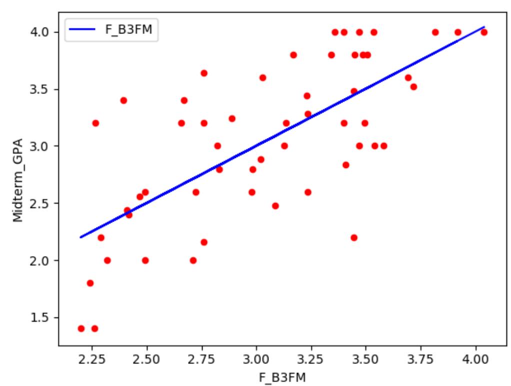

Fig. 2: The midterm GPA (red dots) plotted against the best three-factor model (F_B3FM), and the F_ B3FM plotted against the F_ B3FM (blue line).

A linear regression analysis was performed for all possible two-factor models, and the significance and R^2 values are summarized in table 4. The best model consisted of the introduction to circuit analysis grade and prior GPA, which had a significance value less than 0.001 with a slightly smaller R^2 value when compared to the other models.

Table 6: Significance and R^2 for each two-factor model. The best two-factor model is highlighted in green.

Elements	Significance	R^2
DSPE_GPA, DiffQ_GPA,	Less than 0.001	0.295
DSPE_GPA, ICA_GPA	Less than 0.001	0.410
DSPE_GPA, P_GPA	Less than 0.001	0.276
DiffQ_GPA, ICA_GPA	Less than 0.001	0.441
DiffQ_GPA, P_GPA	Less than 0.001	0.325
ICA_GPA, P_GPA	Less than 0.001	0.48

The parameters of the best two-factor model can be seen in table 7. It can be seen that while the grade in the introduction to circuit analysis course is more significant than the prior GPA, their p-values are less than 0.05. Models that included the score of the directed self-placement exam and did not include the grade in the introduction to circuit analysis course were the least significant and had the smallest R^2 values.

The fact that the directed self-placement exam score was the least significant factor supports that the exam might not be needed to be given or studied in the future. Another interesting point this the prior GPA was more important than the grade in the differential equations course. This can be explained that the circuit and systems course uses only the Laplace transform portion of the differential equations course.

*Table 7: Best two-factor model parameters to predict midterm 1 GPA. (ns-not significant p>0.05, * 0.05>p>.001, ** p<.001)*

	coef	std err	t	P>|t|
const	-0.6786	0.738	-0.92	ns
ICA_GPA	0.4688	0.096	4.9	**
P_GPA	0.7139	0.241	2.96	*

The midterm GPA is plotted against the function of the best three-factor model (F_B2FM) in fig. 3. This plot looks to be almost the same as the plot for the four-factor and the best three-factor model.

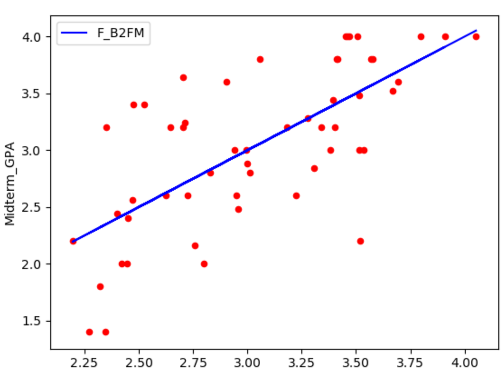

Figure 3: The midterm GPA (red dots) plotted against the best two-factor model (F_B2FM), and the F_ B2FM plotted against the F_ B2FM (blue line).

A linear regression analysis was performed for each factor, and the significance and R^2 values are summarized in table 8. The best model consisted of the introduction to circuit analysis grade. While each factor was significant on its own, the R^2 value dropped even for the grade in the introduction to circuit analysis course indicating that a two-factor model is needed. The parameters of the best one-factor model can be seen in table 9.

Table 8: Significance and R^2 for each two-factor model. The best two-factor model is highlighted in green.

Elements	Significance	R^2
DSPE_GPA,	*0.016*	0.106
DiffQ_GPA,	Less than 0.001	0.240
ICA_GPA	Less than 0.001	0.39
P_GPA	Less than 0.001	0.235

*Table 9: Best one factor model parameters to predict midterm 1 GPA. (ns-not significant p>0.05, * 0.05>p>.001, ** p<.001)*

	coef	stderr	t	P>|t|
const	1.3362	0.306	4.365	**
ICA_GPA	0.56	0.097	5.768	**

IV. Conclusions

While the effect of the workshop could not be measured in a statically significant manner [25], having the workshop could have helped the students indirectly master the learning objectives. The first indirect manner the workshop could have helped students learn was that the instructor of the circuits and systems course also taught the workshop, instead of teaching the exam preparation workshop. This allowed the instructor to improve their teaching in a manner not available before. Another indirect path the workshop could have had was that the students in the workshop could have helped students who were not in the workshop. As a result, the workshop needs further investigation.

Based on the fact that models that do not use the grade on the directed self-placement exam are more significant and have higher R^2 values than those that do, it seems difficult to justify the continued use of the directed self-placement exam. Even though previous studies show that it could be effective in decreasing DFW rates in the author's circuits and systems course, there could be as yet unmeasured benefits for not using the exam. For example, not using the exam could make for a more welcoming learning environment. Additionally, the author has seen some qualified students not take a course just because placement exams exist. This happens even if the exam is not a screening exam.

Given that prior GPA has been used in the past to measure motivation [25-32] and was shown to be a more significant factor than a prerequisite grade [26]. Maybe exceptions to the C or better in the differential equations course could be made for students with a high prior GPA and grade in the introduction to circuit analysis course so that students can graduate on time. Currently, the pre-requisite grade for the differential equations course is a C (not C-).

The midterm one grade for the cohort semester is similar to other semesters. While the grades are not significantly higher, they are not considerably worse. The reasons for this could be that the homework assignments were updated so that students did not have access to old homework solutions, and some homework's were converted to automatically graded homework's via MyOpenMath so that students could get immediate feedback on their learning progress.

Future work could include case studies in the workshop or classroom [33]. Currently the case studies that are provided are old homework solutions.

V. References

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