Student performance in first-year physics: does high school matter?

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Abstract*: At The University of Sydney, approximately one in four first-year physics students have not studied senior high school physics. Previous studies have concluded that taking a high school physics course has a positive effect on student performance in undergraduate physics. To our knowledge, no study has examined whether students who do not study senior high school physics are negatively affected when integrated into a first-year physics class with students who have studied senior high school physics. An educational context was found in which such a study could be performed. Thus, we investigate the consequences of integrating students with different high school physics backgrounds into the same undergraduate physics stream. The sample consisted of 233 first-year physics students. Of these, 109 had studied senior high school physics, while 124 students had not. We investigated the examination performance of matched groups at senior high school and at university. When both groups were integrated into the same Semester 2 physics stream, known as Environmental and Life Science, there was no statistically significant difference in the Environmental and Life Science raw examination marks for two of the three matched groups ($p = 0.421$, $p = 0.157$), and a borderline significant difference for the third matched group ($p = 0.049$). We conclude that students with no background in senior high school physics are generally not disadvantaged in the Environmental and Life Science physics course, when compared with students who have studied high school physics.*

Introduction

Students entering their first year of university often undertake subjects which they have not studied in their final years of high school, such as physics. Depending on the level of mathematics studied in senior high school, students also possess widely ranging mathematical skills. Due to students' differing educational background and experience, a dilemma is raised: how should first year university physics students be divided into streamed classes and taught, without disadvantaging one group of students over another?

Previous studies are divided on the benefit of high school physics on a student's success in undergraduate physics. However, none of these studies investigate the success of undergraduate physics classes in which students with no background in senior high school physics are integrated with students who have taken senior high school physics. This paper reports on such a study at The University of Sydney.

Literature review

Prior research has attempted to measure the impact of high school physics courses on students' success in undergraduate physics (Gifford and Harpole 1986; Hart and Cottle 1993; Alters 1995). These American studies generally found that students who performed well in high school mathematics and physics subjects also did well in undergraduate physics. However, Sadler and Tai (2001) point out that these conclusions were reached by examining only a few variables and forming simple correlations. Consequently, underlying demographic relationships were ignored – for example, university-educated parents could influence the success of their children at high school and in university-level physics. Regression techniques should be employed to take such variables into account. For example, prior research using multiple regression analysis (Champagne and Klophfer 1982; Halloun and Hestenes 1985) showed that high school math and physics courses were only slight factors in predicting student performance in undergraduate physics. Both Champagne and Klopfer (1982) and Halloun and Hestenes (1985) found that student preconceptions of physics concepts affected student success in college physics significantly, and that performance on conceptual tests to identify these preconceptions was a better predictor of success in undergraduate physics grades than senior high school grades.

In the latest known study, Sadler and Tai (2001) concluded that taking high school physics – and high school calculus – has a small, but positive, effect on students' undergraduate physics grades. In fact, calculus had much more impact than taking high school physics on university grades. Here, regression models are required to accurately estimate the predictive value of a high school physics course. For example, by only accounting for a student's studying of high school physics, the predicted university grade is inflated, since taking physics and calculus in high school are strongly correlated with each other.

Methodology/research design

The participants in this study are taken from the group of first year undergraduate physics students commencing at the University of Sydney in 2006. In Semester 1, first year physics students are placed in Regular (REG), Fundamental (FND) or Advanced (ADV) classes according to their high school background in physics. Students who achieved over 90 in senior high school physics were generally placed in the ADV classes, while all other students who had studied senior high school physics were placed in the REG classes. Students with no background in senior high school physics were placed in the FND classes.

In Semester 2, students were divided into the Environmental (ENV), Technological (TEC) and Advanced (ADV) classes. Table 1 shows the number of students enrolled in each Semester 1 undergraduate physics course, and the corresponding numbers of students who studied a particular Semester 2 course. Due to the nature of this study, knowing the senior high school background and marks of the students is a critical part of the study. As the data on the senior high school backgrounds of the students are obtained from another source and some of the information is not complete, we only consider the students for which we have knowledge of their senior high school background.

To evaluate the performance of students in first year physics who had not studied senior high school physics, compared to their peers who studied senior high school physics, we selected all the students who went from the Semester 1 FND class to the Semester 2 ENV class. We call this group 'FND to ENV', or F2E for short. Similarly, we denote the group of students who went from the Semester 1 REG class to the Semester 2 ENV class to be the 'REG to ENV' or R2E group. Thus, the participants in this study are comprised of 124 students in the F2E group, and 109 students in the R2E group. This information is summarised in Table 1.

Table 1. The number of students in each undergraduate physics course is tabulated. We selected two groups of first year students for the study, 'REG to ENV' and 'FND to ENV', abbreviated as R2E and F2E

Semester 1	Semester 2	Sample studied
REG, N = 293	TEC, N = 143	-
	ENV, N = 109	R2E, N = 109
	ADV, N = 2	-
	Dropped Physics, N = 39	-
FND, N = 155	TEC, N = 9	-
	ENV, N = 124	F2E, N = 124
	ADV, N = 1	-
	Dropped Physics, N = 21	-
ADV, N = 141	TEC, N = 7	-
	ENV, N = 10	-
	ADV, N = 122	-
	Dropped Physics, N = 2	-

Results and analysis

We were able to obtain the senior high school data of the students in the sample, as well as data on their Semester 1 and 2 raw examination marks. From Table 1, it is evident that the sample sizes of the studied groups were adequate for data analysis. Exploratory data analysis was performed and all data was found to be normal.

As the objective of the study was to compare Semester 2 examination marks between F2E and R2E groups, it was important to identify matched groups which had similar high school backgrounds and performances. We explored various combinations of senior high school data to identify matched groups. The best match was found by grouping students based on their senior high school mathematics results. As most students were from NSW and had sat the Higher School Certificate (HSC), the matched groups were obtained by selecting all the students whose highest levels of mathematics were Mathematics, Mathematics Extension 1, and Mathematics Extension 2, as shown in Table 2. We did not consider students who did not attempt any mathematics course for their HSC, or those who studied General Mathematics, as the sample sizes were inadequate.

Table 2. The number of students in the R2E and F2E groups who had studied a certain level of mathematics is tabulated

Highest level of mathematics studied	**R2E**	**F2E**	**Total**	**Sample**
Mathematics	14	20	34	Matched group 1
Mathematics Extension 1	43	40	83	Matched group 2
Mathematics Extension 2	34	20	54	Matched group 3
Total	91	80	171	

Having identified matched groups with similar high school backgrounds, we used t-distribution analysis to perform a 2-tailed test of significance on key HSC examination results. In particular, we examined the Chemistry, Mathematics, and Universities Admission Index (UAI) mean scores of each matched group, subdivided into the R2E and F2E groups. Since $p > 0.05$ for all tests of significance, there was no statistically significant difference in the senior high school performance of the R2E and F2E groups (Tables 3, 4 and 5). Thus the high school backgrounds of the R2E and F2E matched groups are similar.

We have not performed any analysis on the examination scores of the R2E and F2E matched groups in Semester 1, as students studied different courses (REG or FND) and thus attempted different examination papers. An investigation into the differences in subject matter between the Semester 1 REG and FND course, and its subsequent effect on preparing students for Semester 2, was considered beyond the scope of this paper. We now return to the primary objective of the study, which is to compare Semester 2 examination marks between the R2E and F2E groups when both are integrated into the same ENV physics stream.

Using t-distribution analysis and a 2-tailed test of significance, there was no significant difference in the ENV raw examination marks for two of the three matched groups ($p = 0.421$, $p = 0.157$), and a borderline significant difference for the third matched group ($p = 0.049$). We therefore conclude that students with no background in senior high school physics are not significantly disadvantaged in the ENV physics course, when compared with students who have studied high school physics.

While the difference between the ENV examination scores of the R2E and F2E matched groups is not significant, it appears by inspection that taking a high school physics course has a weak effect on undergraduate physics performance. Consequently, our results agrees with the latest and most comprehensive study to date performed by Sadler and Tai (2001), in which they concluded that taking high school physics has a positive but weak effect on students' undergraduate physics grades.

Table 3. Matched Group 1, comprised of Mathematics students, N = 34

	Sem1CourseID	N	Mean	Std Deviation	Std Error Mean	p-value for Test of Significance between REG and FND means
UAI	REG	14	88.70	6.55	1.75	0.240
	FND	19	91.74	7.65	1.75	
Chemistry	REG	12	81.42	7.67	2.21	0.994
	FND	16	81.44	7.43	1.86	
Mathematics	REG	14	82.71	7.76	2.07	0.315
	FND	20	79.80	8.48	1.90	
Sem2Total	REG	14	45.29	11.89	3.18	0.049
	FND	20	35.65	14.49	3.24	

Table 4. Matched Group 2, comprised of Mathematics Extension 1 students, N = 83

	Sem1CourseID	N	Mean	Std Deviation	Std Error Mean	p-value for Test of Significance between REG and FND means
UAI	REG	42	92.56	4.69	0.72	0.355
	FND	40	93.58	5.24	0.83	
Chemistry	REG	37	82.86	5.94	0.98	0.646
	FND	33	83.48	5.23	0.91	
Mathematics	REG	43	89.70	4.76	0.73	0.753
	FND	40	90.05	5.39	0.85	
Mathematics Ext1	REG	43	82.60	9.24	1.41	0.892
	FND	40	82.30	11.08	1.75	
Sem 2Total	REG	43	44.79	14.87	2.27	0.157
	FND	40	40.33	13.54	2.14	

Table 5. Matched Group 3, comprised of Mathematics Extension 2 students, N = 54

	Sem1CourseID	N	Mean	Std Deviation	Std Error Mean	p-value for Test of Significance between REG and FND means
UAI	REG	34	93.69	4.31	0.74	0.071
	FND	19	96.03	4.65	1.07	
Chemistry	REG	28	84.00	4.88	0.92	0.561
	FND	16	82.81	8.62	2.15	
Mathematics Ext1	REG	34	91.06	4.29	0.74	0.752
	FND	20	90.65	4.99	1.12	
Mathematics Ext2	REG	34	82.56	6.98	1.20	0.146
	FND	20	85.30	5.84	1.31	
Sem2 Total	REG	34	47.50	16.24	2.79	0.421
	FND	20	43.50	19.51	4.36	

To further confirm our findings, we plotted students' Semester 1 raw examination marks against their Semester 2 raw marks for both the REG and FND streams, as shown in Figure 1. We recall that the main difference between the R2E and F2E group is that students in the R2E group have undertaken senior high school physics, while students in the latter group have not. There is no systematic bias in either stream, indicating that no particular sub-group of students is advantaged or disadvantaged. Furthermore, the correlation coefficients are almost identical. Thus we see that a student's relative performance to their peers in the Semester 1 examination is similar to the student's relative performance in the Semester 2 examination, regardless of whether they were in the R2E or F2E group, and irrespective of whether the student had studied senior high school physics or not.

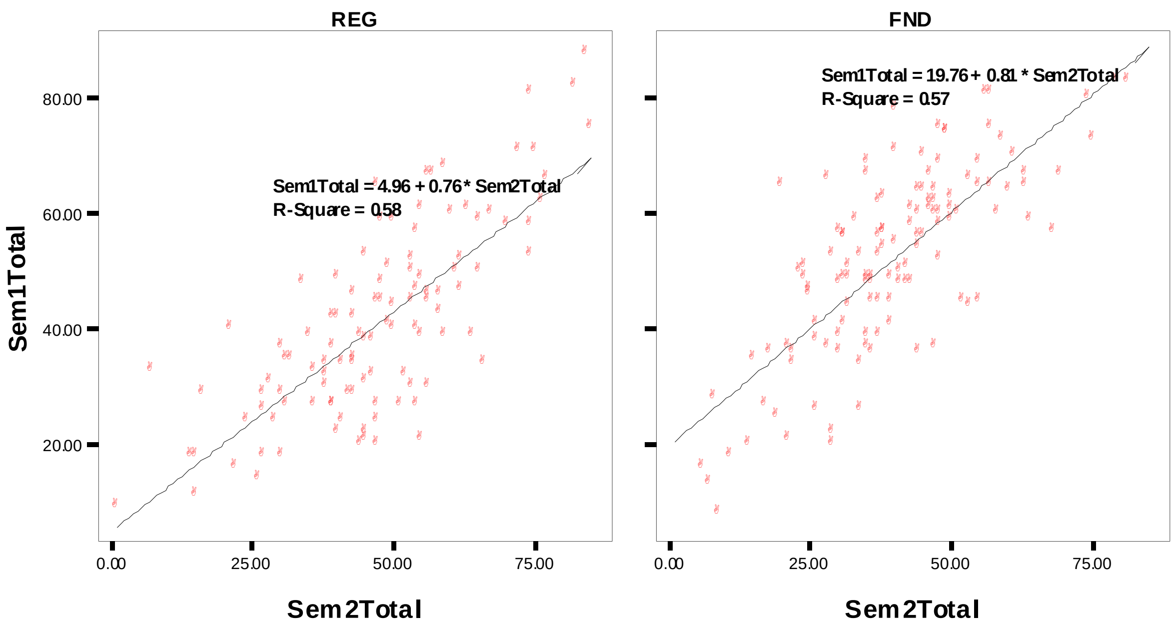

Figure 1. Semester 1 examination marks versus Semester 2 marks for the Regular and Fundamentals streams

By inspection of the constant term in the least squares regression equation, it appears that the FND students performed better in the Semester 1 examination than the REG students. However, this result is not meaningful as the two groups attempted different papers and the marks have not been scaled.

Conclusion

Matched groups were found with no statistically significant difference in HSC performance, signifying that each of the matched groups had a similar senior high school background. We then investigated the performance of the R2E and F2E groups in the common Semester 2 examination. After comparing the Semester 2 examination performance of the F2E and R2E students within each of the matched groups, it was found that there was generally no statistically significant difference in the Environmental raw examination marks for two of the three matched groups. Thus we conclude that students with no background in senior high school physics are generally not disadvantaged in the Environmental physics course, when compared with students who have studied high school physics.

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