High school pedagogy: The influence of high school in-class activities and events on introductory college physics success

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ABSTRACT: This study explores how students' grades in introductory college physics are influenced by the pedagogy used in their high school physics classes. The success of college science professors is often judged on the basis of the success of their students. This disregards the 18+ years of experiences with which students come into their physics classroom. This study aims to answer the question of what pedagogy best prepares students for introductory college physics. This quantitative study analyzes data from the Factors Influencing College Science Success (FICSS) project, focusing specifically on the data relating to college physics. The data from the FICSS Project were collected from 128 first-semester introductory college science courses taught in fall 2002 and fall 2003 at 55 four-year colleges and universities (36 public and 19 private) located in 34 states. The study used a linear regression model to determine which factors from high school physics, specifically pedagogy, influence introductory college physics performance, while controlling for student demographic and academic background. The results indicated that only two high school pedagogies have a significant influence on introductory college physics performance: the frequency of individual work and of small group work. Small group work was a negative predictor of college physics success while

individual work was a positive predictor. In addition, small group work was more detrimental to female students than male students.

INTRODUCTION

The research question guiding this study is: which pedagogies used in high school physics have an influence on performance later in introductory college physics, controlling for demographic and academic background variables? A secondary question to the main research question is: are certain pedagogies used in high school physics more detrimental to students of a specific gender?

Existing Research Literature

As a teacher, one of the most important considerations, besides determining what content to cover, is how to teach the material. Teachers are often evaluated based on the effectiveness of their teaching, which is reflected in the performance of their students. The pedagogy which a teacher uses in teaching the material can vary from classroom to classroom. There is a dearth of empirical data available to teachers on which methods are not only most effective in teaching particular subjects, but also most influential in helping their students succeed if they take college introductory science courses in the same subject. On the topic of high school physics and pedagogy in the classroom, there have been a series of studies focused either in the high school classroom or the college classroom that highlight key teaching paradigms that can help improve performance. The following are the most relevant findings from articles in examining which high school pedagogies influence success in introductory college physics:

- *Teachers need to balance cooperative work with time to process and reflect.* “Although cooperative group work gives both students and teachers time to process their thoughts, during class-wide discussions and interactive lectures instructors should take special care to allow ample time for students to process and reflect on questions and comments" (Dufrense, Gerace, Leonard, Mestre & Wenk, 1996, p. 5). This is of particular concern because it suggests that, though there are benefits to class-wide discussion and interactive classroom environments, teachers should make sure students are able to process the information they are learning properly.

- *Several practices in the high school classroom can have a negative impact on a student's course grades.* This study found that certain pedagogies, "including the overuse of demonstrations, time spent on pre-class preparation for laboratories and assignment of class projects" (Tai, Sadler, & Mintzes, 2006, p. 59) have a negative influence on students' success in future college science course. This study suggests that high school teachers have an influence on their students through the teaching methods they utilize in their classroom. Though this study looked at a collection of college science courses simultaneously, including biology, chemistry, and physics, it suggests similar trends would appear when looking college introductory physics courses in isolation, and that high school physics teachers can play a role in helping their students succeed in college.
- *Physics content and pedagogy are better suited for male students.* "The historical dominance of males in physics translates into education practices by defining what physics content (e.g., topics such as mechanics and electromagnetism) and methods (e.g., type and format of problems, labs, contexts) are considered suitable for studying in high school physics" (Hazari, Tai, & Sadler, 2006, p. 848). This research literature suggests that there will be a differential influence of high school pedagogy on gender, advantaging male students.

- *Student engagement is often lacking.* "The traditional high school physics class tends to follow a model of isolationist pedagogy with an excessive amount of reliance on textbooks and rote problem solving, even though these types of isolated learning models have been found to be detrimental to the success of students later on in college and university physics (Sadler & Tai, 2001)" (cf. Hazari, Tai, & Sadler, 2007, p. 850). Despite the data and research showing that isolated learning is detrimental, teachers still employ these traditional techniques. Even with the abundance of resources on interactive teaching techniques, there is an apparent barrier to using these pedagogies in the classroom. These studies suggest that mechanical and regimented classroom activities will be negative predictors in our study.

Despite the numerous studies that have been conducted looking at pedagogy, there is little empirical research examining the longitudinal influence of high school pedagogy on success in introductory college physics. Research literature does not provide strong support for one specific approach or another. The lack of consensus leaves teachers confused on what pedagogy to use in their classroom. The purpose of this study is to generate empirical evidence that provides insight into the discussion of the most effective high school pedagogy, which hitherto has been primarily argued on an anecdotal level or with a classroom-specific focus. We provide a quantitative analysis of the relationship between a high school teachers' choice of pedagogy and their students' success in later college introductory physics courses.

Gender Interactions

It is important to examine the role of gender interactions in the classroom, as well as why it is important to aim to achieve gender equality in physics and the sciences, in general. There are several rationales that can be used to justify why gender equality is important. The three central arguments include:

- *New perspectives.* Kenway and Gough (1998) observe that the intellectual potential of females is an untapped source for furthering scientific knowledge. The rationale is that a diversified group of professionals in the field of science introduces new perspectives.
- *Increased public interest*. Females represent roughly half of the population. It is reasonable to anticipate public interest to increase if a greater portion of females were engaged and involved in scientific pursuits.
- *Equal access to opportunity*. Careers in science are highly profitable in terms of money, status, and influence. There should be the opportunity for every member of society to have the same chance to pursue these paths. Currently, there are more barriers to entry for women in science than their male counterparts. . Urry (2003) writes “in physics departments around the country, women are feeling ill at ease, out of place, not at home”

Given the above argument, the next step is to determine how to reach this goal of achieving gender balance in the sciences, specifically physics. This is the difficult portion that researchers, policy makers, students, teachers, and others alike are aiming to answer. However, “working out the practical implications of a new approach to content, pedagogy, and assessment methods takes time and experimentation” (Seymour, 2001, p. 86). This study focuses on answering a part of the question by identifying factors from high school that influence physics performance in university. It is important to understand the effectiveness of high school physics teaching practices and the relationship between these practices and gender in order to best prepare female students for future physics classes and give them the full opportunity to pursue science.

METHODLGY

The Study

The benefit of analyzing the effect of a variety of factors together is that it offers insight not only into their individual influence, but into their relative effects while controlling for the other factors in the model, such as known demographic and academic background variables that explain academic performance in college introductory physics. Through this multi-variable analysis, the best predictors can be identified. This makes sense for another reason as well: students experience these variables simultaneously and not in insolation. This means that failing to consider these variables together paints an incomplete picture of the role of high school pedagogy on success in introductory college physics.

The parent study from which this study was derived collected a wide range of data that made it possible to assess the influence of high school pedagogy. *Factors Influencing College Science Success (FICSS)* was funded through the Interagency Education Research Initiative and administered through the National Science Foundation. The FICSS study focused on identifying predictors in introductory college science (Hazari, Tai & Sadler, 2007). This included physics, chemistry, and biology. The study was conducted through a large-scale survey of 128 first-semester introductory college science courses taught in fall 2002 and fall 2003 at 55 four-year colleges and universities (36 public and 19 private) located in 34 states. The methodology is that of an epidemiological survey where researchers rely on the natural variation of the diversity of student background and experience, rather than a forced control groups.

To develop the FICSS survey, a preliminary research study was conducted in 1994 (Sadler & Tai, 2001). This study included interviews with twenty-two introductory college science professors and twenty high school students regarding factors and predictors influencing the academic performance of high school students in their introductory college courses. To establish validity after the survey was created, there were a series of student focus groups, as well as discussions with teachers and professors. These focus groups and consultations recommended the revision of items on the survey. Reliability was established through a test-retest study with 113 participants, which found the 90.7% of students responded with at least adjacent choices and 60.0% responded with exactly the same response on both administrations of the test (Hazari, Tai, & Sadler, 2007). The final survey consisted of 66 items that question students regarding the content, pedagogy, and assessment method in their last high school biology, chemistry, or physics class, their academic background and levels of completion in science and mathematics, their performance in those science and mathematics courses, as well as demographic information. Included in the survey was a section in which the college professor reported the student's grade at the completion of the introductory college science course.

The Sample

Among the students in the FICSS sample who were in introductory physics courses, there were those who had taken high school physics as well as those who had no high school physics experience. Since this study is focused on the influence of events in the high school physics classroom, the sample was further narrowed to only those students who had taken high school physics. There were 1215 students who did not report on whether they had taken physics or not. In addition, the sample included a small subsample of graduate students. The graduate students were removed from the sample. There were 53 graduate students as well as 2 students who reported multiple responses for grade level and 79 who reported other. In addition, any fields that included multiple responses were removed. The inability to discern the true value for these items made the data unreliable. When there were fields with missing data, we removed the student from the sample. This resulted in a total of 1327 students in our final sample that was used for modelling.

Table 1 provides a summary of the distribution of universities/colleges in the final sample. It shows both the number of surveys collected and number of surveys in the final sample. The number of surveys collected is in most cases an underestimate of actual enrollment. We did not anticipate 100% participation in the survey. The number of surveys included in our sample reflects the number of surveys remaining after the data was “cleaned”.

TABLE 1

School Location and Sample Distribution by Class

School/University	State	Surveys Collected [A]	Sample Number [B]
1	AK	138	41
2	AZ	108	17
3	AZ	258	125
4	CA	81	22
5	CA	25	6
6	CA	289	92
7	CO	53	12
8	GA	55	19
9	GA	143	79
10	IA	64	2
11	ID	105	10
12	IL	114	44
13	IN	78	30
14	IN	11	8
15	IN	97	12
16	KS	317	69
17	KY	82	12
18	KY	15	2
19	KY	276	76
20	LA	399	55
21	LA	271	23
22	MA	75	62
23	MD	250	145
24	MI	57	18
25	NC	21	7

26	NE	17	1
27	NJ	63	39
28	NY	65	16
29	OR	119	51
30	PA	73	36
31	PA	80	42
32	SC	13	5
33	TN	71	5
34	TN	26	10
35	TX	23	12
36	TX	100	40
37	UT	135	15
38	WA	128	58
39	WV	115	9
Total		4426	1327

[A] Number of surveys collected may differ from actual enrollment

[B] Number of students included in sample

Controls, Predictors, and Outcome

Demographic and academic variables were used as controls. The demographic variables included highest parental education (indicators of socioeconomic status), minority (an aggregate race control variable), ethnicity (Hispanic), high school type (public, private) and gender (male, female). The academic control variables included highest high school math enrollment, year in university (freshman, sophomore, junior, senior), and SAT mathematics score. These variables were identified and chosen as control variables by referencing previous studies of introductory college science performance (Sadler & Tai, 2001; Tai et al., 2005)

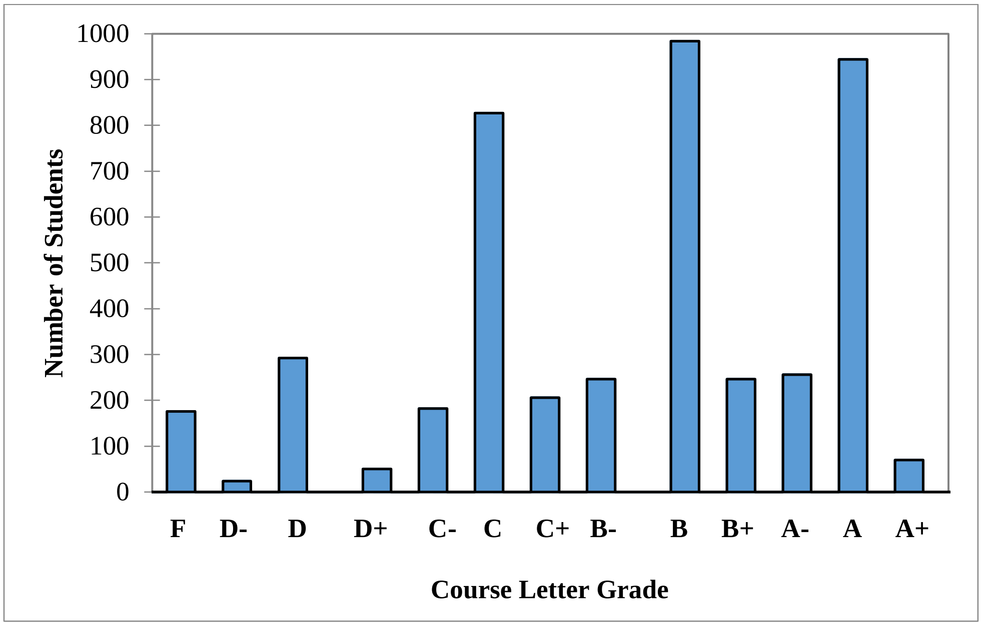
The focus predictor variables in this study were the pedagogy variables. These include nine different activities and events in the high school physics classroom: lecture frequency, whole class discussions, small group work, individual work, everyday examples, test/quiz frequency, community projects, teaching classmates, and exam preparation. These variables were defined by the number of occurrences per semester. Students reported the frequency of pedagogies as follow: Very Rarely, 1/Month, 1/Week, 2-3/Week, and Everyday. Through linear recode, these responses were then transformed to frequency per semester, with Very Rarely = 1 Day/Semester, 1/Month = 4 Days/Semester, 1/Week = 18 Days/Semester, 2-3/Week = 45 Days/Semester, and Everyday = 90 Days/Semester.

The outcome variable is performance in introductory college physics, on a scale of 0-100. The final grade was reported by the university professor. It is important to acknowledge that different grading methods were used at different university and by different professors. Some professors only report full-letter grades (A, B, C, etc.), others used pluses and minuses (A+, A, A-, B+, etc.), and others reported on a scale of 0-100. All these different grading schemes were converted to a 100-point scale, by the following breakdown: A+=98, A=95, A-=91, B+=88, B=85, B-=81, etc. This approach was based on the approach used in similar studies on introductory college science performance (Sadler & Tai, 2001; Tai et al., 2005). The final outcome variable was GRDPRCNT and is a value between 0 and 100. The average grade was 81.7 ± 11.8, which translates to a B-. The distribution of grades across students in introductory college physics can be seen in Figure 1. In examining student grades in introductory physics, it important to note that grades do not necessarily reflect learning or understanding. Grades in introductory college physics act as a measure of whether the student will be able to continue in science. This is because large introductory courses in college physics tend to act as a gateway to all future courses in physics. “Failure in these courses closes those career options and presses students towards non-science fields, negating years of preparation and aspiration” (Sadler and Tai, 2001, p. 112). Thus, performance is a critical for maintaining students within physics, and science in general.

For more information on the FICSS survey items, a sample survey can be accessed from http://www.cfa.harvard.edu/smg/ficss/research/survey.html.

FIGURE 1

Course Letter Grade Distribution



Modeling

The research question was investigated by an ANCOVA linear regression model evaluated in XLSTAT. ANCOVA is defined as the analysis of covariance and is used to control for one or more factors. The ANCOVA analysis can handle both quantitative and categorical variables. The regression model allows us to predict outcomes based on one or more predictor variables.

A preliminary analysis was run to examine the level of correlation between variables. This was required to make sure that highly correlated variables were considered and if needed, combined into a composite. The preliminary analysis highlighted potential issues of redundancy when building the model in later iterations. In building the model, the individual significance as well as the significance of the variable within the model were all carefully considered. Table 2 shows the correlation matrix for the focus variables.

TABLE 2

Correlation Matrix for Pedagogy Variables

Variables	Small Group	Individual Work	Lecture	Whole Class Discussion	Everyday Examples	Test/Quiz	Community Projects	Teaching Classmates	Exam Preparation	GRDPRCNT
Small Group	**1.000**	0.293	0.058	0.356	0.272	0.177	0.171	0.315	0.139	-0.038
Individual Work	0.293	**1.000**	0.181	0.232	0.263	0.196	0.120	0.219	0.119	0.020
Lecture	0.058	0.181	**1.000**	0.244	0.238	0.086	-0.051	-0.046	-0.036	0.003
Whole Class Discussion	0.356	0.232	0.244	**1.000**	0.353	0.162	0.133	0.193	0.102	-0.031
Everyday Examples	0.272	0.263	0.238	0.353	**1.000**	0.181	0.074	0.174	0.060	0.014
Test/Quiz	0.177	0.196	0.086	0.162	0.181	**1.000**	0.450	0.232	0.340	-0.037
Community Projects	0.171	0.120	-0.051	0.133	0.074	0.450	**1.000**	0.298	0.508	-0.079
Teaching Classmates	0.315	0.219	-0.046	0.193	0.174	0.232	0.298	**1.000**	0.300	0.012
Exam Preparation	0.139	0.119	-0.036	0.102	0.060	0.340	0.508	0.300	**1.000**	-0.049
GRDPRCNT	-0.038	0.020	0.003	-0.031	0.014	-0.037	-0.079	0.012	-0.049	**1.000**

RESULTS AND DISCUSSION

Descriptives

To fully understand the results and implications of this study, descriptive statistics of the sample have been included. Table 3 provides a summary of the mean and standard deviations of two continuous variables: highest parental education and SAT mathematics score. The scale of highest parental education is as follows: 0 = some high school; 1 = high school; 2 = some college; 3 = 4 years college; 4 = graduate school.

TABLE 3

Means and Standard Deviations of Select Continuous Variables across Entire Sample

	MEAN	SD
HIGHEST PARENTAL EDUCATION	2.946	1.035
SAT MATHEMATICS SCORE	621.045	92.581

Table 4 provides a summary of some demographic and academic variables across the sample (N = 1327). It is important to note that gender is uneven across the sample, with females representing only 35.7% of the entire sample. In addition, white students comprised over 70% of the students in the sample. The largest group of students were sophomores, who beat each of the three other class group by over 10%. In considering the academic background of the sample, over half of the students in the sample had been enrolled in some type of calculus while in high school.

TABLE 4

Frequencies and Percentages of Some Student Characteristics

	DEMOGRAPHIC/ACADEMIC CHARACTERISTICS	SUBSAMPLE	PERCENTAGE OF SAMPLE (N = 1327)
YEAR IN UNIVERSITY	Freshman	265	20.4
	Sophomore	525	40.4
	Junior	360	27.7
	Senior	151	11.6
GENDER	Female	464	35.7
	Male	837	64.3
CALCULUS ENROLLMENT	Calculus	254	19.5
	AP calculus AB	395	30.4
	AP calculus BC	144	11.1
RACE (WITHOUT ETHNICITY)	American Indian/Alaskan Native	19	1.5
	Asian/Pacific Islander	153	11.8
	Black	131	10.1
	White	929	71.4
	Multiracial	64	4.9
ETHNICITY	Hispanic	67	5.1

Models

When looking at the nine pedagogy variables in isolation, without the academic and demographic factors, community projects and teaching classmates are significant predictors. This is shown in Table 5. Community projects is a negative predictor and teaching classmates is a positive predictor. However, when controlling for academic and demographic background in Model II, community projects and teaching classmates are not significant. Rather, individual work and small group work frequency are significant factors. These differing results illustrate that it is crucial to consider academic and demographic variables when evaluating what high school pedagogies influence success in introductory college physics.

The four models fitted include a model with only academic and demographic variables (Model I), a model with nine pedagogy variables as well as the academic and demographic variables (Model II), a model with only the significant variables from Model II (Model III) and a model examining the interaction between significant variables from Model II (Model IV). Model I, II, and III are summarized in Table 6 and Model IV in Table 7. The dependent variable of interest was grade percentage, GRDPRCNT, on a scale from 0-100. The variance in GRDPRCNT is 140.11 (standard deviation squared).

Model IV includes the significant variables from Model II as well as the significant interactions between these variables. The only significant interaction was small group work frequency and gender. The significance of this interaction highlights that there is a differential influence of small groups on gender. Figure 2 depicts this interaction. It is evident from this figure that increased frequency of small group work in the high school physics classrooms has a negative impact on all students, but is more detrimental to female students. This interaction is extremely telling and informs us that small group work has a negative main effect and harms female students more.

There is a limitation of the linear regression model that must be noted. The linear regression model does not group students based on university and class, which mean that we have to be careful when analyzing our results. Because of this limitation, there could be something else going on, but it is undiscernible by looking at the current model. For example, it could be the case that students that went to a high school with a higher frequency of individual work were in college courses with professors whose gave grades above the overall grade average in the sample. This would then inflate the significance of individual work. It cannot be said for certain whether or not this is happening in our data. The next step would be to follow up with a hierarchical nested linear model to verify the results at the course level.

TABLE 5

Linear Regression Model Predicting Grade Percentage with High School Pedagogy with Academic and Demographic Control Variables

Variable	*Value*	*Significance*	*Standard error*
Individual Work	0.013		0.009
Small Groups	-0.018		0.010
Lecture	-0.001		0.010
Whole Class Discussions	-0.010		0.009
Everyday Examples	0.010		0.009
Teaching Classmates	0.023	*	0.011
Exam Prep	-0.013		0.017
Test/Quiz	-0.006		0.019
Community Projects	-0.068	**	0.024

TABLE 6

Linear Regression Models Predicting Grade Percentage with Focus on High School Pedagogy

		Model I			Model II			Model III		
	VARIABLE	B	SE	SIG	B	SE	SIG	B	SE	SIG
HIGHEST MATH ENROLLMENT	Algebra I	-4.429	5.135	***	-11.111	8.017	***	-10.619	8.010	***
	Geometry	0.551	3.924	***	-2.225	11.348	***	-0.970	11.328	***
	Algebra II	-7.874	1.437	***	-8.334	1.977	***	-8.388	1.921	***
	Integrated Math	-4.881	2.342	***	-1.407	3.350	***	0.052	3.198	***
	Pre-Calculus	-3.712	1.186	***	-3.445	1.397	***	-3.199	1.356	***
	Trig/Analytic Geometry	-4.676	1.085	***	-5.547	1.247	***	-5.272	1.208	***
	Calculus	-1.463	1.100	***	-1.567	1.214	***	-0.970	1.180	***
	AP Calculus AB	-0.929	1.016	***	-0.721	1.119	***	-0.354	1.094	***
	AP Calculus BC	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
SAT	Math Score	0.02	0.003	***	0.016	0.004	***	0.015	0.004	***
GENDER	Female	2.083	0.559	***	1.884	0.693	***	2.036	0.663	*
	Male	0.000	0.000	***	0.000	0.000	***	0.000	0.000	*
ETHNICITY	No	1.921	1.064	ns	0.625	1.364	ns			
	Yes	0.000	0.000	ns	0.000	0.000	ns			
RACIAL MINORITY	No	1.804	0.638	**	1.823	0.778	**	2.264	0.688	**
	Yes	0.000	0.000	**	0.000	0.000	**	0.000	0.000	**
HIGHEST PARENT EDUCATION	Some HS	-1.984	1.792	*	-3.737	2.445	*	-3.519	2.291	*
	HS	-0.305	0.973	*	-1.081	1.233	*	-1.574	1.181	*
	Some College	0.029	0.735	*	-0.014	0.872	*	-0.048	0.845	*
	4 Years of College	-1.842	0.650	*	-2.219	0.775	*	-2.220	0.754	*
	Grad School	0.000	0.000	*	0.000	0.000	*	0.000	0.000	*
YEAR IN COLLEGE	Freshman	-0.584	0.995	***	-0.758	1.208	***	0.150	1.161	***
	Sophomore	-2.679	0.843	***	-2.161	1.071	***	-1.642	1.036	***
	Junior	0.446	0.856	***	1.198	1.117	***	1.730	1.076	***
	Senior	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
HS TYPE	No HS Reported	-3.416	4.179	ns	2.653	5.297	ns			
	Private Only	1.212	1.492	ns	2.462	1.800	ns			
	Public Only	0.137	1.269	ns	1.124	1.560	ns			
	Baccalaureate	-5.679	3.775	ns	-5.284	4.862	ns			
	Magnet	-1.436	1.885	ns	-1.389	2.216	ns			
	Vocational	1.282	4.768	ns	2.388	5.837	ns			
	Home Schooled	4.297	3.255	ns	2.983	4.283	ns			
	Charter	7.024	4.775	ns	7.489	5.850	ns			
	Parochial	1.239	1.731	ns	2.068	2.067	ns			
	Multiple HS Attended	0.000	0.000	ns	0.000	0.000	ns			

PEDAGOGY	Individual Work		0.027	0.012	*	0.025	0.011	*
	Small Groups		-0.04	0.014	*	-0.040	0.012	*
	Lecture Frequency		-0.014	0.012	ns			
	Whole Class Discussion		-0.006	0.011	ns			
	Everyday Examples		0.009	0.011	ns			
	Teaching Classmates		0.006	0.015	ns			
	Exam Prep		-0.009	0.021	ns			
	Test/Quiz		0.004	0.025	ns			
	Community Projects		-0.025	0.031	ns			
	R^2	0.13		0.126			0.116	
	N (Sample Size)	1847		1284			1343	

*: p < 0.5; **: p < 0.01; ***: p < 0.001; ns: not significant

FIGURE 2

Interaction between Small Groups and Gender

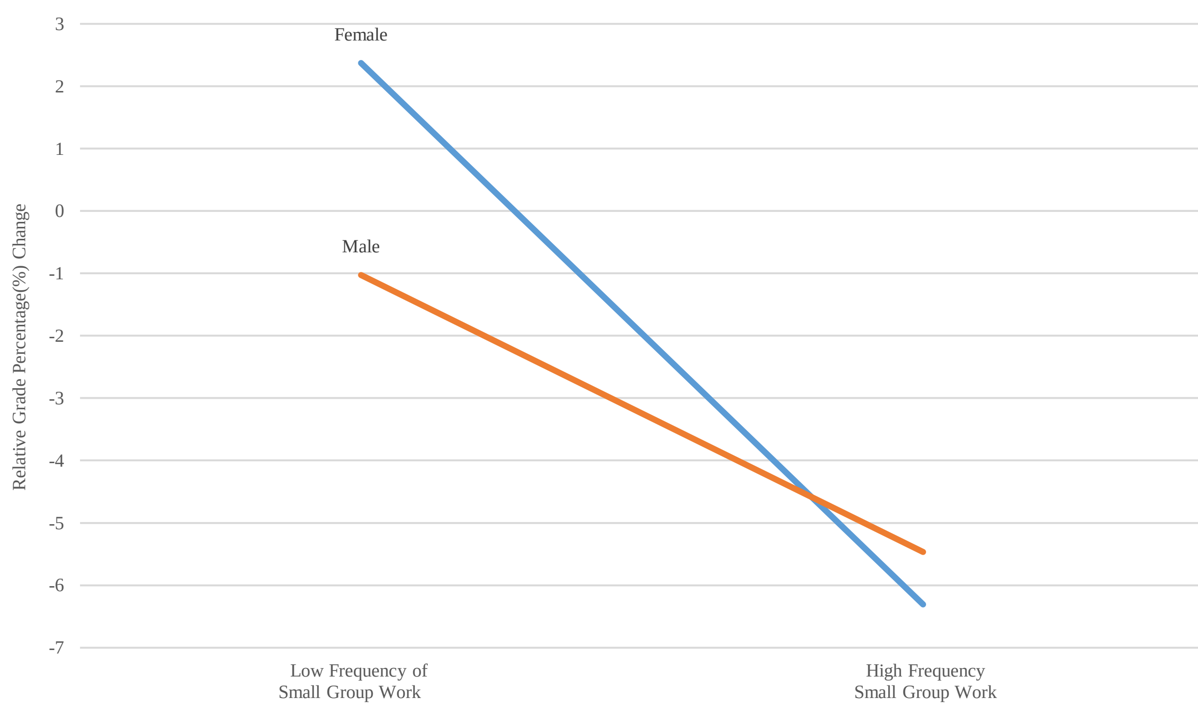


TABLE 7

Model IV: Linear Regression Model Predicting Grade Percentage with Gender Interactions

		VARIABLE	**B**	**SE**	**SIG**
ACADEMIC VARIABLES	Highest Math Enrollment	Algebra I	-10.001	7.970	***
		Geometry	1.478	11.313	***
		Algebra II	-8.343	1.913	***
		Integrated Math	-0.173	3.182	***
		Pre-Calculus	-3.428	1.350	***
		Trig/Analytic Geometry	-5.303	1.205	***
		Calculus	-1.184	1.176	***
		AP Calculus AB	-0.279	1.089	***
		AP Calculus BC	0.000	0.000	***
	SAT Math		0.015	0.004	***
DEMOGRAPHIC VARIABLES	Gender	Female	4.377	1.029	***
		Male	0.000	0.000	***
	Racial Minority	No	2.220	0.685	*
		Yes	0.000	0.000	*
	Highest Parent Education	Some HS	-10.638	3.563	*
		HS	-2.566	1.720	*
		Some College	-0.458	1.317	*
		4 Years of College	-3.659	1.155	*
		Grad School	0.000	0.000	*
EDUCATIONAL VARIABLES	Year in College	Freshman	-0.399	1.757	ns
		Sophomore	-1.816	1.528	ns
		Junior	-0.967	1.602	ns
		Senior	0.000	0.000	ns
VARIABLES OF INTEREST	Pedagogy	Individual Work	0.025	0.011	*
		Small Groups	-0.068	0.038	ns
INTERACTIONS	Gender*Pedagogy	Small Groups*Female	-0.065	0.024	**
		Small Groups*Male	0.000	0.000	**
		R^2		0.132	
		N (Sample Size)		1343	

*: p < 0.5; **: p < 0.01; ***: p < 0.001; ns: not significant

Positive Predictors

The positive predictors of success in introductory college physics are academic, demographic, and pedagogical variables. The academic variables are SAT mathematics score, gender, highest high mathematics enrollment in high school, and year in college. The demographic variable that is a positive predictor is highest parent education. The only pedagogical variable that is a positive predictor is individual work.

It is important to note that SAT mathematics score and highest high school mathematics enrollment are the most significant positive predictors for success, which is backed up by research conducted in the past twenty years. Shumba and Glass (1994) found that mathematic skills were more important than previous content knowledge of a science. This was further backed up in 2003 in a study by Conley. A faculty member in the study stated “basic math skills, are, quite possibly, the most important skill set for student to have mastered coming into a freshman science course. They need to understand why equations work and what each equation says about the physical world” (Conley, 2003, p. 42-44).

The individual work pedagogy variable is one that needs to be discussed in more depth. This result seems contrary to research literature discussing the merits of group learning and cooperative learning techniques. Dufrense et al.’s (1996) research may help to explain this result. Though interactive teaching techniques help keep students engaged, there is a critical need to balance that with individual work to allow the “students to process and reflect on questions and comments” (Dufrense, Gerace, Leonard, Mestre & Wenk, 1996, p. 5). Without this decompression time, students do not have a chance to translate the lessons into their physical understanding of the world, which they can then bring with them into their introductory college physics course.

Negative Predictors

The greatest number of negative predictors are demographic variables. The negative demographic predictors of success in introductory college physics are if the student is Hispanic and if that student is a minority (not including Hispanic). The one pedagogy variable that is a negative predictor is small group work. It is interesting that small group work is a negative predictor because it seems to be a stark contrast to individual work. Though group work often has the underlying goal of facilitating discussion and deeper understanding, working in teams can become cumbersome. Groups of peers may have different levels of understanding and the student with the strongest understanding of the material can get frustrated explaining the minutia of a concept/problem to the struggling students. This can result in one or two students completing the work for the entire group. This interaction in small groups is one hypothesis explaining the significant and negative effect.

It is interesting to note that whole class discussion is not a negative predictor, which is a similar teaching pedagogy in the sense it is collaborative work within a larger group. The key difference between small group work and whole class discussion is the role of the teacher. Often in whole class discussions, the teacher helps to facilitate the conversation and clarify misconceptions. In small groups, the teacher is responsible for several small groups and has to go around checking in on each group individually. This points to the critical job of the teacher. This hypothesis needs to be studied in further depth. Research into the dynamics of small group work and whole class discussion may provide additional insight into the results of this study.

Gender Interactions

The role of gender interactions can be seen in Model IV in Table 7. The interaction between small groups and gender is further broken down in Figure 2. The difference between male and female students is evident. The significance of this interaction highlights that this is a critical event happening in the high school science classroom. The mean frequency of small group work is 31.785, with a standard deviation of 27.013. That means 31.785 days in a semester small group work is occurring in the classroom. If the average semester is 90 days, small group work is happening approximately once every three days. This activity has an overall negative main effect regardless of gender, but is more detrimental to female students.

It is important to discuss what may be happening in these small groups, and why small group work is especially detrimental to female students. Research has shown that females in single sex-physics classes have higher interest level, self-concept, confidence, achievement and persistence (Gillibrand, Robinson, Brawn, & Osborn, 1999; Haussler & Hoffman, 2002). This suggests that the male students are a dominating influence in co-educational physics classrooms. The dominance of male students may be heightened in small group settings, where it is up to the students to take initiative to achieve the set task. High school also tends to be a time of be a time of emotional and personal development for students. This can influence female students through lower self-confidence and a hesitance to actively participate in classes. The combination of this and the dominating influence of male students could be playing out in small group work. Additional research on the gender dynamics in small groups is needed to explore this hypothesis.

NEXT STEPS AND RECOMMENDATIONS

Next Steps

Given the limitations of the linear regression model, the next step would be to follow up with a hierarchical linear model that groups students on the basis of their university and course. Since this study has students nested within courses, a multilevel model consists of three levels of variance: (1) student level, (2) course level, and (3) university/college level. A multilevel model will determine the amount of variability in student course performance on the level of the student versus the course. The results of the hierarchical nested linear model would illuminate whether something else is going on in the data or if our current results are indeed true.

To further examine the gender dynamics of small group work, further research needs to be conducted. To test the validity of our hypothesis on the gender interactions occurring in small groups, there should be a comparative study of single-sex small groups and co-ed groups. The level of variance between these groupings will help shed light onto what is happening.

Recommendations

The main takeaway from this research is that small group work has a negative main effect and is more detrimental to female students. These results should be disseminated to high school physics teachers so that they can use the best pedagogies in their classes. There should be a conscious effort of teachers and professors to reduce the amount of small group work in the classroom. Eliminating or reducing this practice in the classroom will help to address the gender gap and will help high school students succeed in future physics courses.

CONCLUSIONS

Several key insights can be gained from this work. Most notably, the pedagogy used by high school physics teachers in the classroom can have an influence on a student's success in a subsequent college introductory physics course. The retrospective longitudinal analysis conducted in this study provides empirical data on the effectiveness of pedagogy in the classroom. This can then be built upon in future studies. It is also interesting to consider that most high school pedagogies have no significant influence on students' future performance in introductory college physics. The frequency of lecture, whole class discussion, everyday examples, test/quizzes, community projects, teaching classmates and exam preparation have neither a positive nor negative influence on success in college physics. Lastly, small group work has an overall negative main effect, but is more detrimental to female students. Reducing the amount of small group work in the high school physics classroom will help all students to succeed in subsequent physics classes at the college level. Because introductory college science courses act as gateway courses, improved performance opens the door to opportunities in science. Thus, improving the performance of female students helps to provide additional opportunities and is one step in addressing the gender gap.

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