



A supplemental instruction model for engineering physics instruction

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Short Biography – Dr. Hasan Sevim

Dr. Hasan Sevim obtained the degree of B.S. in mining engineering in 1974 from Istanbul Technical University, Turkey, as the valedictorian of his class. He obtained his M.S. and Ph.D. degrees in 1978 and 1984, respectively, from Columbia University, New York. In 1984, he joined the College of Engineering at Southern Illinois University Carbondale as an assistant professor in the Department of Mining Engineering. He served as the Associate Dean of the College of Engineering from 1998 to 2006. He was appointed the Dean of School of Engineering at SIU Edwardsville in August 2006.

Until 2000, most of Dr. Sevim's publications were in mine systems optimization and open pit mine production planning. After 2000, in parallel to his administrative appointments, he published in engineering education.

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Engineering students in a school of approximately 1300 undergraduate students jumped to a 45% average rate of grades D, F, or W (or DFW rate) in University Physics I over the course of multiple semesters. These outcomes existed despite steadily increasing academic preparation of students in each incoming freshman class, as measured by the average ACT composite and math subscores. To address the persistently high DFW rates, the School of Engineering at Southern Illinois University Edwardsville began offering a new Engineering Physics I course to engineering students, beginning in the Spring 2014 semester. This course design includes three hours of lecture per week, closely integrated with two hours of supplemental instruction and two hours of laboratory per week. This paper presents the design of the course, including an assessment-based approach for selection and rotation of supplemental instruction work groups, explores results of the pre- and post-assessments for two semesters of Engineering Physics I, and presents implications for this course as well as for interfaces with subsequent courses in engineering curricula.

Introduction

Engineering programs in the School of Engineering at Southern Illinois University Edwardsville require two semesters of University Physics, a calculus-based sequence with associated labs. These courses are taught in the Department of Physics and require a pre-requisite of Calculus I with a grade of C or better and a co-requisite of Calculus II. University Physics I is typically completed as part of a set of courses common to each engineering student's freshman year experience that also includes an Engineering Problem Solving course as well as Calculus I and II and Engineering Chemistry. As evidenced in Budny et al., difficulty in "high risk" courses such as calculus, chemistry, and physics can contribute to decisions by students not to persist towards engineering degrees¹. Hence the School monitors these fundamental courses and invests resources as needed towards associated retention initiatives to ensure that first year students build a sound foundation for their subsequent studies.

In the Spring 2012 semester, there was a dramatic increase in the rate at which students earned grades of D, F, or W (or DFW rate) for University Physics 1, a traditional lecture-based class with an associated lab. This was largely due to pedagogical issues in a single course in which the DFW rate exceeded 70%. After resolving these acute issues, however, School of Engineering administration noted that the DFW rate had not only dramatically risen in that semester, but was also rising at the same time that the average ACT composite and math subscores for incoming engineering freshmen was also increasing steadily.

In Figure 1 below, the left-hand axis shows the ACT Math subscore for freshmen in the School of Engineering. The right-hand axis shows the DFW rate for University Physics for the Academic Year beginning in a given year.

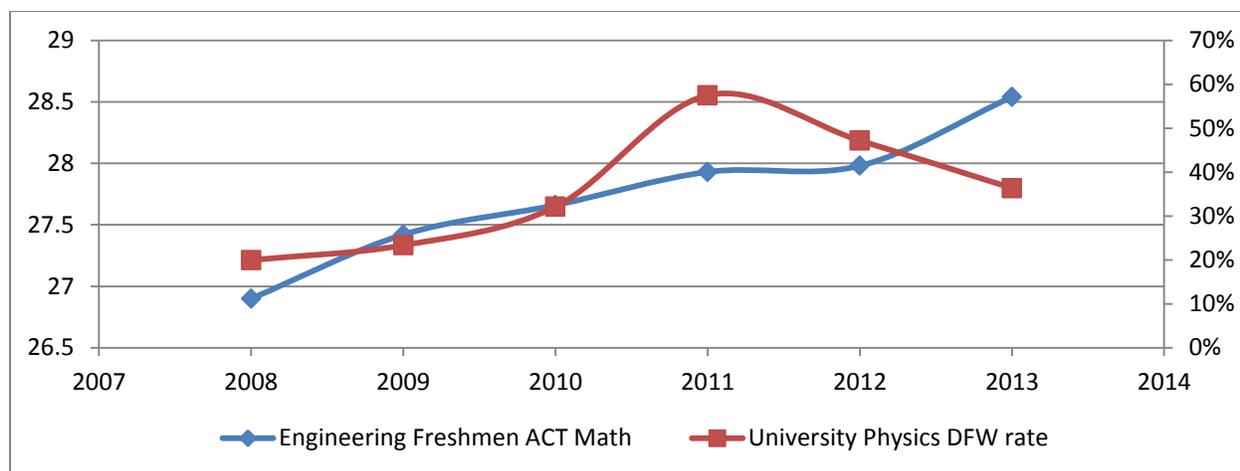


Figure 1: University Physics DFW rates increasing while ACT Math scores increase

As the DFW rate remained above 45% in the 2012-2013 academic year, the School of Engineering elected to introduce a new model for physics instruction for its engineering students. The model and initial results for this course are described below.

Approach for this course

Considerable investigation has been done to improve student learning of physics, including several successful efforts employing active engagement environments for physics instruction. Hake found that students who participate in physics instruction classes with active engagement methods showed higher cognitive gain than students in traditional lecture-based physics classes². Among several examples of active engagement methods are Workshop Physics³, which combines laboratories, lectures, and problem sessions into group workshop sessions guided by an instructor and student assistant; and “Tutorial” physics, in which traditional TA-led recitation is replaced with a small group problem solving session facilitated by a TA⁴.

The School of Engineering introduced Engineering Physics I beginning in the Spring 2014 semester. Given class sizes of up to 60 students, the course design retained traditional lectures, but added a weekly active engagement component. The Engineering Physics I course includes three closely coordinated components: 1) traditional lecture taught by engineering instructors for three one-hour periods per week; 2) weekly related laboratory sessions for two hours per week, and 3) mandatory two-hour supplemental instruction sessions that are held weekly and that count 5% towards the final grade. These group problem solving sessions are facilitated by undergraduate engineering students who have performed well in the course previously and who also possess excellent communication skills. The lecture topics and textbook were kept similar to that of University Physics for comparability between the courses. A series of laboratory experiments were designed for new computer-integrated laboratory equipment. Each of these three components is tightly coordinated to ensure that concepts from lecture are reinforced in supplemental instruction and laboratory sessions.

Canham et al. have found that cognitively diverse teams perform better on problems transferring concepts to new situations than heterogeneous teams⁵. Wiley et al. found that teams with at least

one member with higher math skills perform better in math problem solving groups⁶. Hence in designing supplemental instruction groups, great care was taken to group students in cognitively diverse teams in order to ensure that each group effectively transfers concepts from other class components, but also engages in fruitful discussion that challenges each group member's understanding of physics concepts.

During the first week of the semester, students take the Force Concept Inventory (FCI), assessment test⁷. Groups are assigned using results of the FCI pre-test. Prior to the first problem solving session, students are ranked by FCI score, then divided into four tiers based upon their ranking. Each team is composed of one student from each of these tiers in order to ensure that each team has a diverse composition in terms of their physics preparation and at least one of the better prepared students is in each group.

In the weekly supplemental instruction sessions, the instructor provides problems related to concepts covered during the lecture period for students to solve in groups. Groups are rotated after each exam, again by selecting one student from each tier. This rotation method allows students to work with several classmates over the course of the semester. Students typically will not work with the same group member more than once in a given semester. During the supplemental instruction sections, students are assigned three to four problems to solve as a group during the two-hour period and are encouraged to actively discuss the problems as groups. Supplemental instruction leaders circulate through the aisles of the classroom to provide real-time feedback about problem-solving strategies.

In the final week of the class, students again take the FCI exam to measure their cognitive gain. In addition, they receive feedback related to any conceptual shortcomings evidenced by the post-test results in order to help them study for their final exam.

Results

The DFW rates for Spring and Fall 2014 sections of Engineering Physics are approximately 25%, which is a marked improvement over the rates achieved in University Physics during the previous several semesters. In comparison, the University Physics course began offering optional supplemental instruction and saw an 18% DFW rate in the Spring 2014 and 33% in the Fall 2014 semester, both below the 5-year 39% DFW average for the course. However, a few notable details are shown in Table 1, provided below. Students who had taken a high school physics course prior to taking Engineering Physics achieved a DFW rate of 18%, while students who had not taken a physics course prior to Engineering Physics experienced double the rate, a 40% DFW rate. In addition, students with prior physics experience earned grades of A and B at a much higher rate (49% A and B rate) in comparison to those without this background (28% A and B rate).

Table 1: Success rates for students with and without prior physics experience

	Students who did not take physics in high school	Students who took physics in high school
#	25	76
# DFW	10	14
DFW rate	40%	18%
A	2	13
B	5	24
C	8	25
D	3	11
F	2	0
W	5	3

To further understand student performance, we look at the assessment results from before and after the course. As can be seen in Figure 2, students with prior physics (regular or honors/AP) in high school start and end the course at a much higher level than those without high school physics.

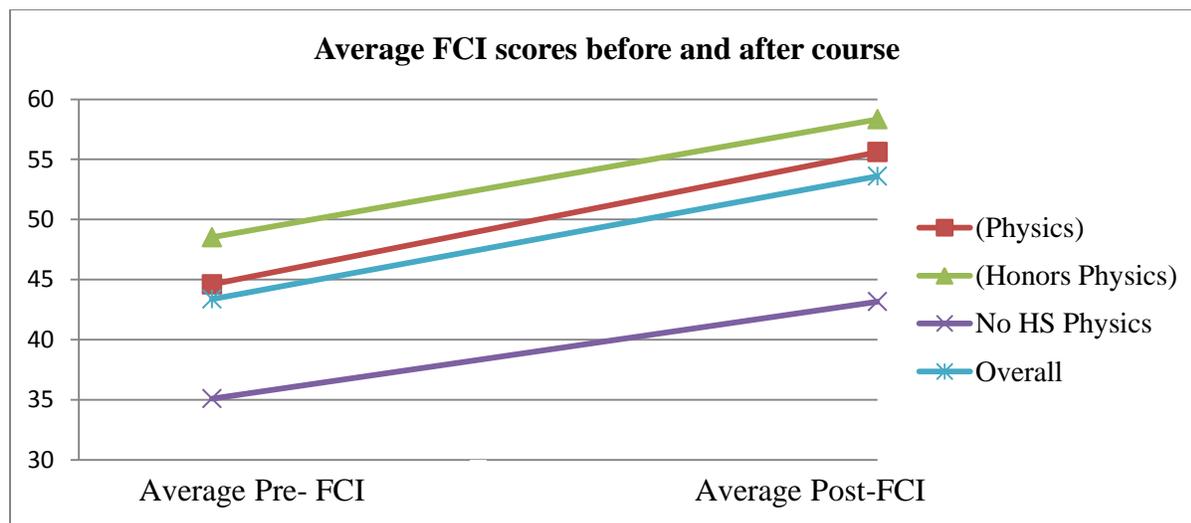


Figure 2: Average FCI scores for Students with and without prior high school physics

The normalized gain between pre-test and post-test further demonstrates this finding. Normalized gain $\langle g \rangle$ is commonly used to quantify the cognitive gain of students as a result of physics instruction. This measure is calculated by dividing the difference between the pre-test and post-test scores by the difference between the maximum possible score and the pre-test score. This measures a student's cognitive gain in comparison to how much the student could possibly gain². As seen in Table 2, the average normalized gain for students in the engineering physics class is 19%. Students with high school physics gained 21% on average. This includes

22% for students with regular physics and 19% for students with Honors or AP Physics. However, students with no prior physics experience started at a much lower initial score and only showed an 11% gain.

Table 2: Average FCI gain for students with and without prior physics experience

	Avg. FCI Gain
High School Physics	21%
(Physics)	22%
(Honors Physics)	19%
No HS Physics	11%
Overall	19%

This parallels findings from Cummings, et al. that found a correlation between pre-test scores for a related assessment tool (FMCE) and normalized gain such that students with higher pre-test scores were able to benefit more from active engagement “studio physics” teaching method⁸.

Performance of students in subsequent classes

The first engineering course to follow Physics I in engineering curricula is Statics. Currently, the Fall 2014 semester Statics class is the only course for which there is longitudinal data for Engineering Physics students’ performance in subsequent courses. In the class, students completing Engineering Physics attained a comparable DFW rate to students from other Physics I classes. However, these students had higher rates of higher grades and lower rates of lower grades, as shown in Figure 3.

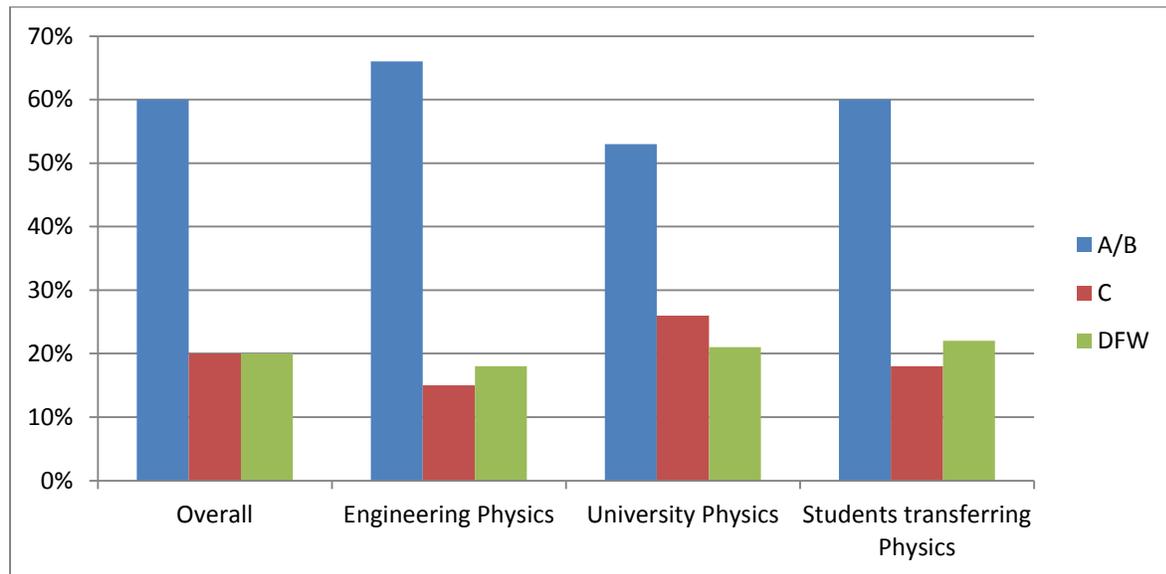


Figure 3: Student performance in Statics class after completing physics I in different venues

These results provide initial evidence that students are better prepared for subsequent classes in engineering curricula and may therefore be better prepared to persist towards engineering studies.

Conclusions

This paper presents the implementation of an engineering physics course design featuring weekly integrated supplemental instruction. Students achieved higher success rates in this course and in the subsequent statics course as a result of this method. Students with no high school experience in physics, however, achieved less cognitive gain in comparison to students who took high school physics. As a result, we are investigating assessments and preparatory coursework for students with no prior high school physics preparation. Additional research is needed to determine other factors that can lead to group and individual success in this format. Such factors could include student learning styles and their initial mental models of physics concepts as they begin the engineering physics sequence. While there is initial evidence that students in engineering physics with supplemental instruction class are well-prepared for subsequent statics class, longitudinal research will determine the degree to which this model of instruction has an impact on student persistence in engineering curricula.

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