

# The Impact of the History of Physics on Student Attitude and Conceptual Understanding of Physics

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**Abstract.** The purpose of this study is to investigate student learning of Newtonian Mechanics through the study of its history and the development of the relevant ideas since the time of ancient Greece. The hypothesis is that not only will students learn the basic concepts of mechanics, but also will develop a more positive attitude and appreciation for physics. To assess the students' conceptual understanding, we administer Force Concept Inventory (FCI) and for the measurement of student attitude change, we employed the Colorado Learning Attitudes about Science Survey (CLASS); both were given as pre and post-tests. Additionally, at the end of the quarter, a survey was given out to see how students perceived the different course components and which ones they found helpful in their learning. This paper will present our preliminary results on such a study.

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## INTRODUCTION

In the past, there have been a few attempts to teach physics through the history of physics or incorporate the history into a standard physics course. Most of the existing literatures are mostly based on speculations. For instance, Herman Erlichson wrote a paper in 1966 about how he incorporated scientific readings from actual scientists into his two-semester course. His reasoning behind the readings was, "we can greatly enrich this course by introducing the student directly to the seminal thought of first class thinkers in the areas of philosophy and history of physics" [1].

Several decades later, research was still being done on the importance of a history of physics course. In 2009, Gerd Kortemeyer and Catherine Westfall wrote a paper on a course taught in both the classroom and as part of a study abroad program in Europe. They compared the differences in how the students responded to an in classroom course and an on site course in Europe. It was noted that the study abroad students, who had more exposure to history of physics and visited historical places where famous experiments were conducted, were able to make more real world connections; while the classroom students mostly related physics to reading the text and knowing and applying equations [2].

Igal Galili conducted a comparison study, in which he discussed using history to teach physics,

specifically optics [3]. He presents two trends: the first based on traditional research performed in several countries and an investigation of students' misconceptions in learning; the second attempting to answer "to what extent the history of physics presents a necessity in teaching physics, or is it merely optional". A conclusion of his is that the history of physics should be intertwined with the normal teaching method of physics (i.e. a traditional modern physics course).

In an article, Raymond Seeger argues physics should be its own history class and not integrated into a history of science class. He notes that a single physics concept is usually not the discovery of a single person, but of many where each contributor is important. He values the impact of the history for its "insights into important lessons of the past, the ensnaring involving of the present, and guiding directions for the future" [4].

These papers did not present a viable systematic approach to using the history of physics for teaching physical concepts. However, they did stress the importance of using a historical approach to teaching physics. In this paper, we present an attempt at a more systematic method to measure the effect of using history context in teaching introductory mechanics.

## COURSE DESCRIPTION

This particular study is based on a *History of Physics* course that was developed at Cal Poly Pomona. This course teaches the history of physics with an emphasis on the development of ideas from the time of ancient Greece to modern times. The course is open to all majors and it counts as an upper division general education elective for all majors or as an advanced elective for physics majors. This data is collected from one class, which was made up of 29 students, who contained a variety of majors. Most of the students completed introductory biology, chemistry, and physics courses with various levels of math ranging from algebra to calculus.

The curriculum consisted of different assignments meant to teach physics and its history. The textbook used was *Physics, The Human Adventure: From Copernicus to Einstein and Beyond* by Gerald Holton and Stephen G. Brush. Throughout the quarter, students were given assigned reading in the textbook and were asked to make discussion questions based on the chapters they read. Selected questions then were handed out in class for small student group discussion. The groups would summarize their discussion and present their answers to the given questions to the class as a whole. These discussions created more of an interactive engagement environment than the traditional format. The students also had two projects to complete: the first was a five-minute storytelling presentation on a single scientist who contributed to physics in some way; the second was a group presentation on the development of a single physics field theory or concept and the scientists related to it [5]. This enabled the students to do research relating to physics and allowed them to familiarize themselves with a certain physics concept(s). Other course components included brief lectures, demonstrations, and a couple of guest speakers. Furthermore, students had online reading and writing assignments, which included view and analysis of short movie clips on physics and the history of physics.

This course focused on concepts and the logical debates with very minimal amount of quantitative mathematical calculations. The relationships among different physical quantities were quantitatively discussed and often compared using proportionality. The course structure did not include any regular numerical problem-solving components.

## RESEARCH METHODOLOGY

To measure the students' ability to apply the concepts of Newtonian physics to everyday life we used Force Concept Inventory (FCI) [6]. The FCI was

given in the first and last week of the quarter to measure the gain in student conceptual understanding during the course.

To obtain the students' initial perception of learning physics and their change of attitude throughout the quarter, we used Colorado Learning Attitudes about Science Survey (CLASS) survey which is a 42 item Likert survey (strongly disagree, disagree, neutral, agree, and strongly agree). The CLASS questions are then broken up into nine different categories to be analyzed more thoroughly [7]. The CLASS survey was also given at the beginning and the end of the quarter.

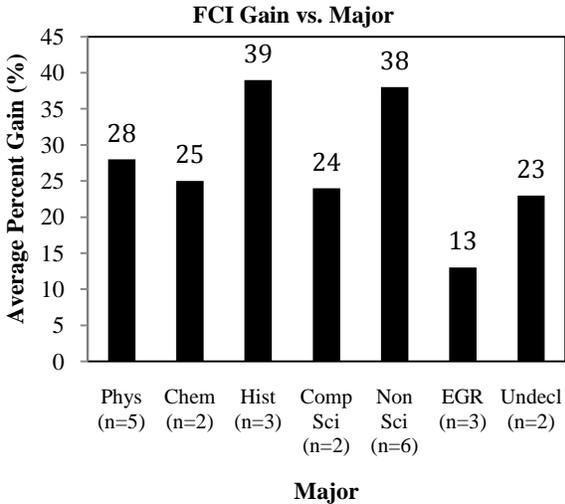
Additionally at the end of the quarter, a survey made up of 18 questions, was given to compile information about student demographics such as gender, major, class status, ethnicity, and math and science background. This survey also was intended for receiving feedback from students about the different course components. The analysis of these three surveys provided us with useful information about the students, their basic knowledge of Newtonian mechanics, and their attitude shift in this course.

## DATA ANALYSIS

Using the FCI pre and post-test results, the normalized gain was calculated for each student using the equation [6]:

$$\langle g \rangle = \frac{(\text{posttest} - \text{pretest})\%}{(100 - \text{pretest})\%} \quad (1)$$

The normalized gain was only computed for students who completed both the pre and post-test. The students' results were then grouped into their respective majors and the average was taken of the normalized gain for each group. The results of the normalized FCI gain for different majors are shown in Figure 1. The normalized FCI gain for the math majors (n=2) was dramatically different from the other majors and from each other. Specifically, one student had a FCI normalized gain of +60% and the second student had a normalized gain of -67%. Due to a very small number of students in this group and their contrasting results, we excluded their data from Figure 1.



**FIGURE 1.** The average Normalized Gain on FCI for different majors (n=23).

Students in all majors showed reasonable conceptual gain. With the exception of the Engineering students, the normalized gain for all the students are comparable to typical gain in traditional introductory physics courses. According to Hake [6], there are three ranges of normalized gain: low (0-30%), medium (30%-70%), and high (70%-100%). Most lecture based traditional courses are in the low range and more interactive courses have medium FCI gain, the high range is not likely to be obtained. He also states that most traditional physics classes have a gain of about 25%. The average overall class gain for this group was comparable to the Cal Poly average FCI gain in introductory physics courses over the past three years. Most of the data collected at Cal Poly Pomona falls in the 25%-35% range. In addition the normalized gain of non-science majors in these courses are often lower than physics and engineering students.

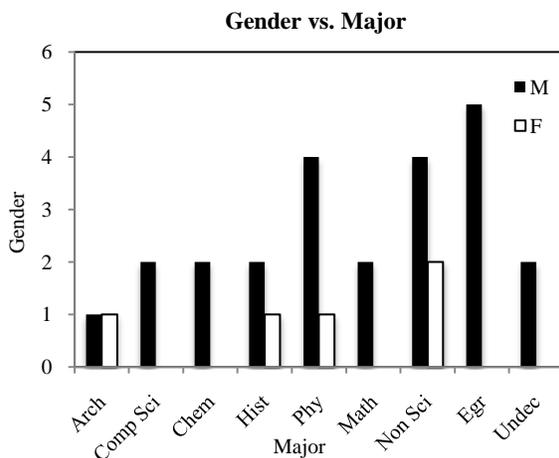
It is somewhat surprising that the history and non-science related majors showed the most gain by falling into the medium range of normalized gain based on Hake's study. This result is inconsistent with FCI gain in typical introductory courses where math and engineering students often score higher [8]. Our results suggest two possible inferences: first, perhaps the familiar context of the history to students with less background in physics (history and non-science majors) made the concepts more accessible to this group; second, conceivably, minimizing the mathematical aspect of physics concepts at the introductory level allows students with less math background (non-science majors) to focus on the concepts without the pressure of learning many equations and fear of heavy calculations.

Once the CLASS results were collected from the students, their attitude shift could then be determined. After favorable results for each question was determined, the percentages of favorable responses were grouped into their respective nine CLASS categories [see Table 1]. Then, the average shift was calculated from the difference of the average pre and post-test percentages. The results of CLASS, Table 1, shows a positive shift in five out of the eight scored categories for student attitude with the highest shift on "Personal Interest" (13%), "Sense Making/Efforts" (10%), and "Real World Connection" (6%).

**TABLE I.** The average favorable data for CLASS with standard error in parentheses.

	Categories	Avg. Pre %	Avg. Post %	Avg. Shift %
1	Real World Connections	78 (5)	84 (4)	6
2	Personal Interest	67 (5)	80 (4)	13
3	Sense Making/Effort	69 (4)	79 (4)	10
4	Conceptual Connections	56 (4)	55 (6)	-2
5	Applies Conceptual Understanding	49 (4)	49 (6)	0
6	Problem Solving General	68 (5)	70 (4)	2
7	Problem Solving Confidence	67 (5)	68 (4)	1
8	Problem Sophistication	45 (4)	44 (3)	-2
9	Not Scored	50 (7)	52 (7)	2
	Overall	61	65	3

The final survey collected the student demographics. It was found that the class was primarily male with only a handful of women. Figure 2 represents how many of each gender were in each represented major. These students also varied in class status, ethnicity, etc. Students mostly liked the demonstrations shown in class, but especially liked learning the history behind physics concepts. However, they disliked the homework, which is typical, and also disliked the book and lack of lectures. It is interesting that these students prefer lectures instead of being interactive since an interactive environment is more beneficial for learning.



**FIGURE 2.** The number of males and females in each group of majors.

## CONCLUSIONS

Based on these results, we found that teaching physics in the context of its history increased our students' interest in physics and their sense making ability; further, at the end, students were able to draw a better connection between physical concepts and the real world. It was especially useful for non-science majors who often don't have a strong interest in math and science [9]. Perhaps learning the history behind basic physics concepts had raised more interest and motivation, which led to improved conceptual learning and increased appreciation for physics. Although small, the CLASS data shows a positive shift on student overall attitudes for learning physics, which is better than some results in introductory physics courses [10].

FCI results showed the interactive nature of the course and the class discussions had a positive effect on the students learning of the concepts. The students were between the low and medium ranges of gain and mostly above the average 25% gain for traditional physics classes. As shown for this particular class, the history and non-science related majors showed the most gain. According to the CLASS results, the students made more sense of the concepts since Sense Making/Effort had one of the highest shifts. Also, Personal Interest and Real World Connections had the other two highest shifts, which is crucial to learning physics. The results suggest that use of history can improve conceptual understanding and make a positive impact on student attitudes. However, the negative shifts on Problem Sophistication and Conceptual Connections are important aspects that require further study and analysis.

## FUTURE WORK

We realize the limitations of our study; for example, due to the small number of students involved in this study the results cannot be generalized at this point. However, in the upcoming school year, we plan to repeat this study with a different group of students, perhaps with some small alterations. For instance, we might experiment with a different textbook, or modify the student projects. However, an interactive discussion part of the course will continue to be the leading course element. We would like to know if different groups of students and a slight modification of the course in history of physics, would lead to similar results, or possibly better, in terms of FCI gain and attitude shift.

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