Incorporating DOD Research and Historical Materials into a Second-semester Introductory Calculus-based Physics Course

Dr. Mary Yvonne Lanzerotti, U.S. Military Academy

Dr. Lanzerotti is an Assistant Professor in the Department of Physics and Nuclear Engineering at United States Military Academy (West Point, NY). She has conducted research presented at 2017 ASEE on learner-centered teaching techniques in her classes at Air Force Institute of Technology, where she was an Associate Professor of Computer Engineering. She has also held positions at IBM at the Thomas J. Watson Research Center, where she was Instruction Fetch Unit Integrator of the POWER4 microprocessor and co-author on the POWER6 introduction paper at ISSCC. She is author or co-author of six patents and 22 technical journal articles. She is a member of Phi Beta Kappa, the American Physical Society, and is a Senior Member of the IEEE. She received her A.B. summa cum laude from Harvard University, M. Phil. from University of Cambridge (U.K.), and her Ph.D. from Cornell University, all in physics. Her primary research interests are electronic warfare and complex signal processing in the RF domain, and hardware security.

Capt. Kyle Wilhelm, United States Military Academy

Captain Kyle Wilhelm is an instructor in the Core Physics Program with the Department of Physics and Nuclear Engineering at the United States Military Academy. He graduated from the United States Military Academy in 2008 with a Bachelor of Science Degree in Nuclear Engineering. Most recently, he earned a Master of Science Degree in Nuclear Engineering from the Pennsylvania State University in State College, PA in 2017. His research interests include radiation detection and nuclear physics.

Capt. William M. Meier, United States Military Academy

William M. Meier is an Assistant Professor of the Department of Physics and Nuclear Engineering at the United States Military Academy (USMA). He received his B.S. in nuclear engineering from USMA in 2007 and his M.S. in nuclear engineering from the Georgia Institute of Technology in 2016. His research interests include radiation detection, nuclear power, and quantum optomechanics.

Krista Watts, United States Military Academy

Colonel Krista Watts is an Academy Professor in the Department of Mathematical Sciences at the United States Military Academy (USMA). She is a 1996 graduate of USMA with a Bachelor's of Science in Operations Research. Krista also holds a Master's of Science in Operations Research from the Naval Postgraduate School and a PhD in Biostatistics from Harvard University. She is the current Director of the Operations Research and Statistics Program in the Mathematical Sciences Department at West Point and serves on several other committees and governance bodies at USMA. She has been an active duty Army officer since 1996, serving in a variety of tactical and operational assignments. Her research interests focus on applied statistical analysis and include Bayesian Methods for Effect Estimation, and analysis of relationships between nutrition, fitness, and obesity in the general population and the military.

Ms. Susan M. Lintelmann, United States Military Academy

Susan Lintelmann is Manuscripts Curator in the Special Collections Division of the USMA Library. She provides exhibits and classes in collaboration with faculty in the departments of English, History, and Geography. She also supplies reference services for local and remote researchers. Ms. Lintelmann holds a B.A. in English and Latin from Wells College, an M.A. in Latin from Trinity College, and an M.Lit. in Comparative Literature from the University of St. Andrews (Scotland). She received an M.S. degree in Library Science from Columbia University.

Ms. Suzanne M. Christoff J.D., United States Military Academy

Suzanne M. Christoff is the Associate Director for Unique Resources at the United States Military Academy Library. She received her Juris Doctor from Pace University School of Law in 1997 and serves as an Assistant Professor in the Department of Law at the United States Military Academy.

Incorporating DOD research and historical materials into a second-semester introductory calculus-based physics course

Abstract

This paper describes the impact of learner-centered teaching techniques on student learning in a second-semester calculus-based physics course required for physics and engineering majors at a government undergraduate institution in the United States. Some students also take this course as part of their engineering track or as an elective. The course contains four blocks of physics concepts: circuits, waves, gases and fluids, as well as modern physics. Two interventions are introduced in each of the four blocks. These interventions are real-world technical mini-sessions targeting defense applications, and real-world mentorship mini-sessions introducing key physicists and engineers through primary source materials including oral histories and diaries of alumni who have taken physics at the institution since the 1800s.

The circuits block discusses mechanical computers created to defeat Enigma in the US and UK, the invention of the integrated circuit, and the Manhattan Project. Students are shown the Dayton Codebreakers website (http://daytoncodebreakers.org) and the Nobel Prize Speech of Jack Kilby in which he mentioned that the "turning point" for the transistor "came from two highly visible military programs in the 1960s – the Apollo moon mission and the Minuteman missile." Students are shown the Einstein-Szilard letter posted at Atomic Heritage.org. In the waves block, students are shown an interview with Bill Wilcox, Oak Ridge Historian, in which he discusses General Groves who led the Manhattan Project in WWII. Students are shown original telegrams describing the Hiroshima and Nagasaki missions in August 1945.

In collaboration with the institutional library's Unique Resources Staff, relevant archival records and manuscripts materials are displayed throughout the semester. Sections of these manuscripts that mention physics concepts and equations studied by previous students during the past two centuries are highlighted for the current students to read.

The course assesses student technical knowledge with two mid-term exams. There is one comprehensive final exam. There is a 10-session laboratory program. Required problems are the same for all students. Each instructor can assign unique homework problems and quizzes.

The research is carried out by assigning students to one of two groups (intervention group and control group). This paper measures the student learning in the course with the use of a pre-test/post-test knowledge gain assessment of course physics concepts. Three instructors are collaborating to offer the intervention to 46 cadets. The two of the previous instructors and one additional instructor are teaching the same physics course but do not offer the intervention (64 students are in the non-intervention group). On the first day of the course, students in the intervention group take a multiple-choice pre-survey consisting of 14 questions related to physics equations covered in the course, 5 questions related to student preparation, and four free response questions. Students in the control group take the same multiple-choice pre-survey with the free response questions removed.

Introduction

The mission of West Point is to develop leaders of character for the Army of the United States of America who will thrive in a complex security environment [1]. Graduates of West Point must be able to successfully lead soldiers in a conventional war against ISIS, counter-insurgency against Taliban forces in Afghanistan, training operations with allies in Europe, Africa, and Asia, nation-building with foreign politicians, militaries, and businessmen, and a myriad of other tasks. Due to these broad missions, the military academy prepares graduates by educating, training, and mentoring them over a 47-month experience [1,2]. By design, cadets receive a unique liberal arts education and are enrolled in separate academic, physical, and military programs. The academic program has a STEM focus where each cadet must earn a B.S. in their respective discipline while passing a plethora of required courses.

One of the required courses for all students is a university level, calculus-based, one-semester physics course. For students earning a science or engineering degree, a second course of university level physics is required. In this course, DOD research and oral history interventions were implemented to measure the effect upon knowledge gain.

In the second semester physics course, cadets study circuits, waves, fluids, and modern physics. The circuits material begins with DC circuits, transitions to AC circuits, and finalizes with transformers and electrical power transmission. The waves section consists of mechanical, sound, and electromagnetic waves. Wave interference, the Doppler effect, and Young's double-slit experiment are also examined. In fluids, the students learn about Bernoulli's, Pascal's, and Archimedes' principles. The last section of modern physics consists of the photoelectric effect, Compton scattering, lasers, and De Broglie wavelength.

United States Military Academy (USMA) History, Digital Collections, and Unique Resources

The Unique Resources of the U.S. Military Academy Library include documentation of the history of West Point and its alumni. The Collections feature diaries, letters, telegrams, and manuscripts, some of which were donated by alumni [3,4].

West Point was a fortification in the American Revolutionary War, and the Academy was founded on the site in 1802. Early cadets spent their first year learning not only Mathematics, but French, the language of most contemporary military manuals. This initial, pragmatic blend of the arts and sciences evolved into the broader structure of today, balanced to produce the liberal education that is the goal for 21st century graduates.

The Unique Resources (Table 1) attest to this long-held integrated approach. The collaborative project proposed by the Department of Physics and described in this paper was a welcome opportunity to employ staff records, textbooks, letters and diaries in the cause of providing some historical context for two centuries of physics education.

Table 1. Special Collections Resources.

Special Collections Resources
Letters of CDT George Cullum USMA 1833, 9 Sept 1831 and 16 June 1832 [31]
Letter of CDT John Pope USMA 1842, 24 Nov 1839 [32]
Letter of CDT Ulysses S. Grant USMA 1843, 18 July 1840 [33]
Letters of CDT William Dutton USMA 1846, 19 Oct 1842 and 3 Sept. 1844 [34]
Natural & Experimental Philosophy Notebook of CDT James Runcie USMA 1879 [35]
Diary of CDT Charles H. Barth USMA 1879 [36]
Letters of CDT George S. Patton USMA 1909 [37]
Letters & Diary of CDT Richard Von Schriltz USMA 1941 [38,39]
Letters of CDT Henry S. Lowe USMA 1961 [40]
Letters of CDT Curt Esposito USMA 1963 [41]
Academic Board (Staff Records) 1818-1836 [42]
Civil War Telegrams of GEN Joseph Mansfield USMA 1822 [43]
World War II Diary of GEN George S. Patton USMA 1909 [44]
Documents concerning the atomic bomb mission to Hiroshima, GEN Leslie R. Groves USMA 1918 [45]

Background: Pre-test/Post-test Knowledge Gain Assessment

The literature contains multiple published studies that discuss pre-test/post-test knowledge gain assessment and how the use of pre-test/post-test methodologies provides an objective measurement of knowledge gain [5-9]. For example, Delucci's 2014 study discusses measuring student learning in social statistics using a pre-test/post-test study of knowledge gain [5]. Angelo and Cross' 1993 book discusses classroom assessment techniques [6]. Nilson's 2012 book focuses on research-based resources for college instructors [7]. Walvoord published a practical guide to assessment in 2010 [8]. The pre-post methodology is similar to that of one of the co-authors at the Air Force Institute of Technology [9] which presents a three-year study of a two-course graduate sequence and employed a pre-test/post-test methodology with teaching techniques of Felder and Brent [10] to assess student learning using learner-center teaching techniques, one of which was Real-world mini-sessions in industry, defense, and security. A statistically significant improvement was observed in student performance for some courses when the Pre-Diagnostic and Post-Diagnostic evaluations results were compared.

The Second-Semester Calculus-Based Introductory Physics Course

The second-semester calculus-based course is taught in sections of 12-18 cadets. There are Regular sections and Advanced sections, grouped approximately by student GPA. During the course, the instructors prepared short videos describing the physics for subsequent offerings of the course in a flipped classroom format referred to as Thayer 202 (T21) [11-14]. Among the regular sections, the intent of the R1 class instructor was to maximize the understanding and application of physics. This instructor was not concerned with teaching to maximize performance on graded events or the course. He minimized the instruction of "tricks" and focused upon utilizing the concepts and equations in problems or applications.

Each of the Advanced sections received the same level and method of instruction during each lesson. The only alteration was the addition of the historical references into the lesson plan for the Advanced intervention group A1 (see Table 2).

All of the students in the second-semester course completed nine laboratory experiments in formal groups and one in-lab writing event. Each lab group submitted a report on each experiment and the report consisted of a results, analysis, and conclusion sections. All of the experiments examined physics concepts that were part of the course material. In the writing event, students were tasked with analyzing and discussing provided data in a two-page manuscript, and the provided data mimicked the results of a previous lab. The objective of the laboratory program is for students to execute experimental procedures to examine physical phenomena, analyze the data, and communicate the results.

Student Demographics

The majority of students enrolled in this course are engineering majors (Mechanical Engineering, Civil Engineering, Systems Engineering, Electrical Engineering, Nuclear Engineering, and Environmental Engineering) as shown in Table 2. A few students are physics or space science majors. Students in other majors are also shown (Economics, History, Defense and Strategic Studies, Life Science, Chemistry, Environmental Science, Geospatial Information Science, Psychology).

The GPA of the students prior to starting the course is shown in Table 2. The results in the table show that the typical GPA is approximately 3.0 with a standard deviation of approximately 0.5.

Table 2. Student demographics

Section	**Type**	**Average GPA prior to course**	**Engineering Majors**	**Space Science or Physics**	**Other majors**	**Engineering Management or Engineering Psychology**	**Computer Science**
R1	Control	2.98 ± 0.51	9	0	1	1	2
	Intervention	2.81 ± 0.60	6	1	2	2	0
R2	Intervention	3.06 ± 0.55	6	1	3	1	0
R3	Control 1	3.29 ± 0.52	7	1	5	3	0
	Control 2	3.57 ± 0.39	10	0	5	1	2
A1	Control	3.51 ± 0.50	7	4	1	1	1
	Intervention	3.57 ± 0.60	9	3	1	1	1

Teaching Practices of Participating Instructors

The instructors completed the Teaching Practices Inventory (TPI) developed by Weiman and Gilbert [15]. The TPI was proposed in 2014 as a new tool to characterize teaching in mathematics and science at the college and university level. The inventory scores two categories of teaching practices: those practices that support learning and those practices that support teacher effectiveness. For example, practices that support learning are (see Table 2 in [Weiman14]) knowledge organization, long-term memory and reducing cognitive overload, practice, feedback, metacognition, and group learning. Practices that support teacher effectiveness are those that connect with student prior knowledge and beliefs, feedback on effectiveness, and gain relevant knowledge and skills (see Table 2 in [15]).

The course "extent of use of research-based teaching practices" (ETP) histogram generated according to the scoring rubric of Weiman et al. [15] in the seven sections in this study is shown in Fig. 1. Instructor R1 had the highest ETP score per course of 46 for the intervention section and an ETP of 45 for the control section. Instructor R2's section had an ETP of 44. Instructors A1 and R3 had ETP's of 41 for their sections.

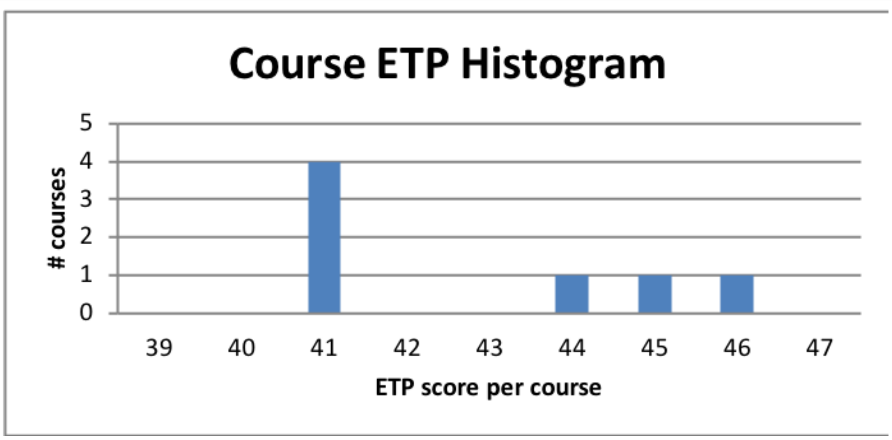


Figure 1. Teaching Practices

Pre-Test/Post-Test Methodology

This research evaluated student learning with a pre-test/post-test knowledge gain assessment composed of 15 questions asking about the variables and units in 15 of the equations that students learn in the course (See Fig. 2). One of the questions asked about an equation that was not included in the finalized syllabus; answers to this question were therefore not included in the analysis presented in this paper. In this survey, students were also asked four additional questions regarding what success meant for them; about their preparation for the course including which previous courses they had taken in mathematics, physics, and chemistry; and about their expectations for the instructor.

A second portion of the pre-test/post-test offered to the intervention groups asked about student attitudes toward learning the material in the course. In this section of the survey, students were asked questions about whether they feel they might enjoy learning about oral history and DOD research in the course and whether they feel that these activities might contribute to their learning. Other approaches that are being taken at undergraduate institutions to change student attitudes towards introductory physics include studio physics at Michigan State University [16-18].

Physics 206: Physics I.
Pre-Course Diagnostic

Name: ___________________________________ Date:___________________________________

Instructions: Please circle your answer and show calculations. Note: At least one question has (e) as the answer. To receive full credit when the answer is (e), please write the correct answer in the box.

1. In a **circuit** equation, $i(t) = \frac{dq}{dt}$, what quantity does the term $\frac{dq}{dt}$ represent?

a. Charge, Coulomb.	b. Change of charge with respect to time (current), Ampere.	c. Inductive reactance, Ohm.	d. Capacitive time constant, second.	e. None of the above (fill in):

2. In a **circuit** equation known as **Ohm's Law**, $V = iR$, what quantity does the term i represent?

a. Charge, Coulomb.	b. Change of charge with respect to time (Current), Ampere.	c. Inductive reactance, Ohm.	d. Capacitive time constant, second.	e. None of the above (fill in):

3. In an equation for a **charging capacitor**, $q(t) = C\mathcal{E}\left(1 - e^{-\frac{t}{\tau_C}}\right)$, what quantity does the term τ_C represent?

a. Charge, Coulomb.	b. Change of charge with respect to time (current), Ampere.	c. Inductive reactance, Ohm.	d. Capacitive time constant, second.	e. None of the above (fill in):

4. The unit fF represents a unit of capacitance and is equal to how many Farads?

a. 10^{15} Farads	b. 10^{9} Farads	c. 10^{-9} Farads	d. 10^{-15} Farads	e. None of the above (fill in):

5. In an equation for an **inductor**, $X_L = \omega_d L$, what quantity does the term X_L represent?

a. Charge, Coulomb.	b. Change of charge with respect to time (current), Ampere.	c. Inductive reactance, Ohm.	d. Capacitive time constant, second.	e. None of the above (fill in):

6. In an equation for a **wave**, $k = \frac{2\pi}{\lambda}$, what quantity does the term k represent?

a. Wavelength, meter.	b. Distance, meter.	c. Acceleration, $\frac{\mathrm{m}}{\mathrm{s}^2}$.	d. Capacitive time constant, second.	e. None of the above (fill in):

7. In the equation for a **string**, $v = \sqrt{\frac{\tau}{\mu}}$, what quantity does the term μ represent?

a. Current, Ampere	b. Tension, Newton.	c. Speed, $\frac{\mathrm{m}}{\mathrm{s}}$.	d. Mass density, $\frac{\mathrm{kg}}{\mathrm{m}}$.	e. None of the above (fill in):

8. In the **Doppler equation**, $f' = f\frac{v \pm v_D}{v \pm v_S}$, what quantity does the term f represent?

a. Focal length, meter.	b. Frequency, Hertz (Hz).	c. Net force, Newton.	d. Friction force, Newton.	e. None of the above (fill in):

Figure 2. Pre-course survey (page 1).

Course Delivery: DOD Research

The instructors in this project worked together to prepare a few slides describing examples of DOD Research [19-24] related to the physics concepts in each Block. For example, in Block 1, the Manhattan Project was utilized for intervention material due to its historical significance in World War II and copies of telegrams in the West Point Special Collections. In class, a summary of the Manhattan Project and LTG Leslie Groves was briefed. An interview of Bill Wilcox, an Oak Ridge Historian, was watched during the intervention too. At the end of the intervention, the instructor directed cadets to visit Special Collections, because physical telegrams reporting the detonation were made available for viewing, shown in Fig. 2. This intervention was developed because the telegram copies are a unique artifact at West Point, are created by electrical signals and circuits, and the nuclear physics aspects of the detonation are applicable to the later modern physics section.

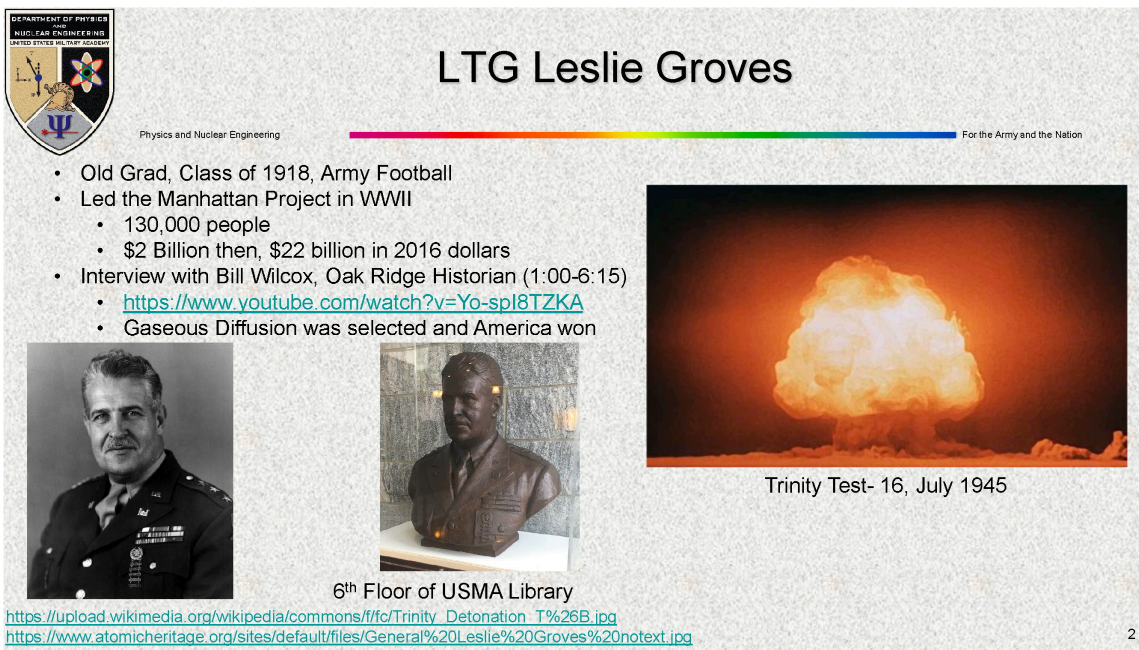


Figure 3. Block 2 – DOD Research.

Course Delivery: Historical Materials

Working with the Library's Unique Resources Staff [3,4], the instructors in this project prepared a scavenger hunt for the items listed in Table 1. These items mention physics and expose students to original diaries and letters on display during the semester. Students were encouraged to record the name of each cadet who wrote a few sentences discussing physics concepts. For example, on

July 18, 1840, Ulysses Grant wrote to his cousin discussing a principle of physics related to the inverse square law of the intensity of light. This letter is on display in the library with a transcript (See Fig. 5 for letter and transcript). Students also heard the voices of some of the scientists, such as Charles Townes whose voice was played during Block 4 (Modern Physics) [25].

PH206 Board Problems, Fall 2018 **Name: ____________________**
Lesson 26

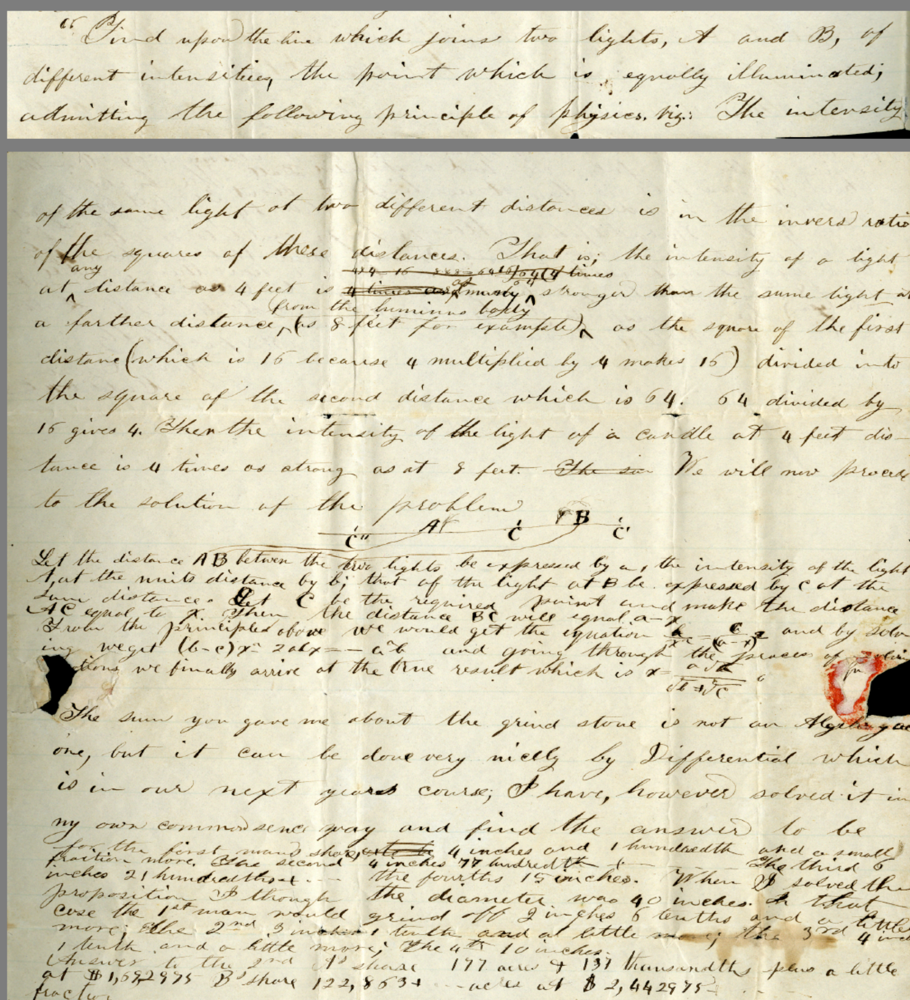
We for the first time attended Chemical Experiments today – Prof Bailey is a perfect gentleman, more cannot be said. We have just commenced Mechanics – Prof Bartlett – We have 450 pages of it, and seven hundred and four of Chemistry.
7. Cadet Letter of ______________________________
July 18, 1840
Find upon the line which joins two lights, A and B, of different intensities, the point which is equally illuminated; admitting the following principle of physics, viz.: The intensity of the same light of two different distances is in the invers [sic] ratio of the squares of these distances. That is, the intensity of a light at any distance as 4 feet from the luminous body must be 64 stronger than the same light at a farther distance (as 8 feet for example) as the square of the first distance (which is 16 because 4 multiplied by 4 makes 16) divided inot the square of the second distance which is 64. 64 divided by 16 gives 4. Then the intensity of the light of a candle at 4 feet distance is 4 times as strong as at 8 feet. We will now procede to the solution of the problem.
8. Cadet Diary of ______________________________
March 21, 1879
This Integral Calculus is just getting away with me. I do not see any sense or fitness in any of it. The author remarks, in one place, that the further investigation of the subject is allowed to the ingenuity of the student. I am glad of this for it will doubtlessly be the extent of my researches.
September 30, 1879
Had a lecture in Phil and Chem today. This made our cup of joy run over. But that Phil lecture must be handed in to-morrow and this makes things look less joyful.
October 3, 1879
Have a hard lesson in Phil for to-morrow. It is about the trajectory of a projectile, considering the opposition of the air.
November 14, 1879
Had a lecture in Phil on the subject of friction. Ragged in Chem. Had to explain manuf. of steel. Rained just enough to get us out of dress parade. Barbour got 10 extras and 20 confinements for staying in the ante-room instead of going in + riding. He was so sore that he was afraid of falling off, and thought that Godfrey would not notice his absence, but he was mistaken.
9. Cadet Diary of ______________________________
May 12, 1880
Had lecture in Phil today on Polarized Light.
10. Cadet Diary of ______________________________
September 26, 1938
I thank thee Dearest God for letting me go proficient in Physics.
September 27, 1938

PH206 3 3
Fall 2018

Figure 4. Transcript of Scavenger Hunt with a few cadet quotes about physics.

Cadet Letter of Ulysses H. Grant. July 18, 1840.

Find upon the line which joins two lights, A and B, of different intensities, the point which is equally illuminated; admitting the following principle of physics, viz.: The intensity of the same light of two different distances is in the invers [sic] ratio of the squares of these distances. That is, the intensity of a light at any distance as 4 feet from the luminous body must be 64 stronger than the same light at a farther distance (as 8 feet for example) as the square of the first distance (which is 16 because 4 multiplied by 4 makes 16) divided inot the square of the second distance which is 64. 64 divided by 16 gives 4. Then the intensity of the light of a candle at 4 feet distance is 4 times as strong as at 8 feet. We will now procede to the solution of the problem.



"Find upon the line which joins two lights, A and B, of different intensities the point which is equally illuminated; admitting the following principle of physics, viz: The intensity of the same light at two different distances is in the invers ratio of the squares of these distances. That is, the intensity of a light at any distance as 4 feet from the luminous body is 64 times stronger than the same light at a farther distance (as 8 feet for example) as the squar of the first distanc (which is 16 because 4 multiplied by 4 makes 16) divided into the square of the second distance which is 64. 64 divided by 16 gives 4. Then the intensity of the light of a candle at 4 feet distance is 4 times as strong as at 8 feet. ~~The so~~ We will now procede to the solution of the problem

C'' A C B C'

Let the distance AB between the two lights be expressed by a, the intensity of the light A, at the units distance by b; that of the light at B be expressed by c at the same distance. Let C be the required point and make the distance AC equal to x. Then the distance BC will equal a−x. From the principles above we would get the equation $\frac{b}{x^2}=\frac{c}{(a-x)^2}$ and by solving we get $(b-c)x^2-2abx=-a^2b$ and going through the process of solutions we finally arrive at the true result which is $x=\frac{a\sqrt{b}}{\sqrt{b}+\sqrt{c}}$.

The sum you gave me about the grind stone is not an Algebraic one, but it can be done very nicely by Differential which is in our next years course; I have, however solved it in my own commonsence way and find the answer to be for the first man's share 4 inches and 1 hundredth and a small fraction more. The second 4 inches 77 hundredths + ... The third 6 inches 21 hundredths + ... the fourths 15 inches. When I solved the proposition I thought the diameter was 40 inches. In that case the 1st man would grind off 2 inches 6 tenths and a little more; the 2nd 3 inches 1 tenth and a little more; the 3rd 4 inches 1 tenth and a little more; the 4th 10 inches.
Answer to the 2nd A's share 177 acres & 137 thousandths plus a little fraction at $1,692975 B's share 122,863+ acres at $2,442975

Figure 5. Cadet Ulysses Grant writing about a principle of physics, the inverse square law of the intensity of light.

Results

Preliminary results in Table 3 show that an increase in point score in the post-test compared with the pre-test is statistically significant for both the control groups and the intervention groups (see the p-values that are shown in the table). Additionally, normalized learning gains achieved by the sections exceed 50% for all of the groups except for one control group [26-28]. Normalized learning gains are high for most sections and exceed 84% for section R1. These high gains are attributed to the instructor's attention to detail and emphasis on core physics concepts as presented earlier.

Table 3. Pre-Survey and Post-Survey

Section	Type (Control or Intervention)	Average Pre-Survey out of 14 points (N)	Average Post-Survey out of 14 points (N)	p-value [1, 2, 3]	Average Normalized Learning Gain (Pairwise) (N)	Average Points Increase (Pairwise)
R1	Control	8.9 ± 1.8 (N=14)	13.2 ± 1.0 (N=14)	8.1E-08 [1]	0.85 ± 0.16 (N=14)	4.3 ± 1.6 (N=14)
	Intervention	8.1 ± 2.1 (N=16)	13.3 ± 0.7 (N=16)	1.3E-07 [1]	0.84 ± 0.18 (N=15)	5.1 ± 2.1 (N=15)
R2	Intervention	9.3 ± 1.8 (N=11)	12.5 ± 1.0 (N=11)	7.2E-05 [2]	0.69 ± 0.22 (N=10)	3.4 ± 1.8 (N=10)
R3	Control	9.3 ± 2.0 (N=9)	10.5 ± 2.3 (N=14)	0.096 [3]	-0.15 ± 1.3 (N=9) 0.25 ± 0.54 (N=8)	0.5 ± 4.1 (N=9) 1.8 ± 2.3 (N=8)
	Control	9.0 ± 2.5 (N=17)	12.1 ± 1.3 (N=17)	4.6E-05 [2]	0.57 ± 0.38 (N=17)	3.1 ± 2.5 (N=17)
A1	Control	9.6 ± 2.4 (N=16)	13.4 ± 0.93 (N=17)	5.5E-06 [1]	0.82 ± 0.41 (N=16)	3.8 ± 2.4 (N=16)
	Intervention	9.1 ± 2.4 (N=17)	12.6 ± 1.3 (N=16)	1.1E-06 [1]	0.76 ± 0.18 (N=14)	3.9 ± 1.7 (N=14)

[1] one sided paired t-test with equal variances
[2] paired t-test with unequal variances
[3] two sample t-test with unequal variances

In reading the post-survey comments about both the oral history and DOD components, we find that we changed the opinion and attitude of the students toward physics (See Tables 4 and 5). These are indicators about the level of interest and enjoyment of the students who are exposed to physics in mandated academic setting. Based on the feedback it appears to us that this component adds a dimension that the students enjoy and may contribute to their life-long learning.

Table 4. Oral Histories – Post-Survey Comments

Section	Did you enjoy learning about oral history of scientists and engineers in this course?	Do you feel that this activity contributed to your learning?
R1	15 out of 16 enjoyed learning; 6 were more positive; 1 was more negative	12 out of 16 enjoyed learning; 4 were more positive; 3 were more negative
R2	11 out of 11 enjoyed learning; 4 were more positive; 0 were more negative	8 out of 11 enjoyed learning; (9 out of 11 if count "Yes, to a well-rounded education"); 4 were more positive; 1 was more negative
A1	12 out of 16 enjoyed learning; 3 were more positive; 3 were more negative	10 out of 16 enjoyed learning; 2 were more positive; 2 were more negative

Table 5. DOD Research – Post-Survey Comments

Section	Did you enjoy learning about DoD research in this course?	Do you feel that this activity contributed to your learning?
R1	16 out of 16 enjoyed learning; 5 were more positive after the course; 0 were more negative	15 out of 16 enjoyed learning; 3 were more positive after the course; 1 was more negative
R2	9 out of 11 enjoyed learning; 1 was more positive after the course; 0 was more negative	9 out of 11 enjoyed learning; 4 were more positive after the course; 0 were more negative
A1	14 out of 16 enjoyed learning; 2 were more positive after the course; 0 were more negative	10 out of 16 enjoyed learning; 4 were more positive after the course; 2 were more negative

Conclusion

Preliminary results show that learning was achieved by all groups in the course, and that the increase in post-test survey scores compared with the pre-test survey scores is statistically significant.

The performance of the students, as measured by normalized learning gain, in the regular sections for instructor R1 (both control and intervention sections) performed at the level of the advanced sections for instructor A1, with similar normalized learning gains observed for all four sections. This result indicates that the students in the R1 sections performed at the level of students that have a GPA of approximately one-half a grade level higher than the GPA of students in the regular sections.

Table 6. Oral Histories – Post-Survey Comments

Section	Did you enjoy learning about oral history of scientists and engineers in this course?	Do you feel that this activity contributed to your learning?
R1	15 out of 16 • "Yes, the discussions on history as well as present day topics were interesting and informative" • "Yes, it was nice to see real life applications" • "This is the most interesting part"	12 out of 16 • "Yes: Most importantly, help remember PRC equations…" • "Yes I believe it did. It allowed me to see the value in what I was learning." • "Not towards course success but overall knowledge" • "It might not have helped with physics but it showed applications."
R2	11 out of 11 • "I loved it" • "Yes, it is interesting to know where all this came from. It makes things easier to remember." • "Yes, it gave me information about the things that we were learning" • "I actually enjoyed learning about everything"	8 out of 11 (9 out of 11 if count "Yes, to a well-rounded education") • "Yes it helped to remember topics" • "Yes it ties certain physics to people and makes it easier to memorize" • "Not really to learning, but yes to a well-rounded education" • "It refreshed my memory to help me for the TEE"
A1	12 out of 16 • "Definitely, was a good change of pace" • "I enjoyed it, maybe should have more because it is very interesting" • "Yes – I always enjoy learning about the men and women behind the seemingly random characters on our PRC"	10 out of 16 • "Academic/personal enrichment yes, not so much the actual learning" • "Helped me understand logic behind things" • "Somewhat, but I feel as if it would have been better to learn about manipulating physics scenarios to find what we are looking for" • "I enjoyed it and it added to my repository of "fun facts" but I don't believe it changed my grade"

While the results do not appear to show a difference between the learning in the control groups compared with the intervention groups, we did find that we improved the attitudes of the students who say that they liked the interventions, and they are completing the course with a positive attitude about physics (See Tables 6 and 7).

Table 7. DOD Research – Post-Survey Comments

Section	**Did you enjoy learning about DoD research in this course?**	**Do you feel that this activity contributed to your learning?**
R1	16 out of 16 • "Yes, But I wish there was more" • "Absolutely, it was good to know what the DOD is doing" • "Yes it was my favorite part" • "Yes it was nice to see real life applications" • "Learning about DOD research was enjoyable"	15 out of 16 • "Yes, I think this can actually be applied" • "I did learn from it, but not in a way that increased performance" • "Yes it gave me a desire to pay attention to the material taught" • "Not towards course success but overall knowledge" • "It showed the importance of the [] in the community"
R2	9 out of 11 • "I really did enjoy it" • "I enjoyed it" • "I did enjoy learning about DOD research"	9 out of 11 • "It definitely could have. Real world applications are always a good way for me to learn things." • "Yes I learned about my profession" • "Yes, as future officers, I think it is important to know that these physics apply to future careers." • "It [refreshed] my memory to help me for the TEE" • "Helped to see military application and pride in history"
A1	14 out of 16 • "Yes, it was cool" • "Yes → good change of pace" • "Yes – it showed us how the material could be [relevant] to our futures"	10 out of 16 • "Academic/personal enrichment yes, not so much the actual learning" • "Helped me see the bigger picture" • "It shows how this could be applicable to Army" • "I don't think it changed my grades but I enjoyed it"

Future Work

To continue this work, a longitudinal study of the course's students can be undertaken to understand the effects of this teaching approach within the context of college level teaching [29]. The effect of improving the attitudes of the intervention students will have effects, as seen in many studies [30]. Their future academic performance could be compared to performance of previous students who participated in the second-semester physics but did receive the same level of intervention. Examining the student performance in future STEM courses against non-STEM courses may yield additional results too.

Acknowledgements

We thank MAJ Jacob Capps (Department of Physics and Nuclear Engineering), COL Corey Gerving (Department of Physics and Nuclear Engineering), Dr. Stephen Finn (Master Teacher Program), Dr. Mark Evans (Master Teacher Program), Dr. Linda Mallory (Institutional Review Board), all at USMA, and the Master Teaching Program at USMA for support of this project.

References

[1] United States Military Academy, USMA Strategic Plan 2015-2021, March 2015.

[2] USMA, "About, The U.S. Military Academy at West Point," Online. Available: https://westpoint.edu/about/SitePages/Mission.aspx.

[3] USMA Library Digital Collections. Online. Available: http://digital-library.usma.edu.

[4] USMA Library, Finding Sources: Special Collections. Online. Available: http://usma.libguides.com/findingsources/physicalitems/specialcollections.

[5] Michael Delucci, "Measuring student learning in social sciences: A Pre-test-Post-test Study of Knowledge Gain," Teaching Sociology, 42 (3), 231-239, 2014.

[6] T. A. Angelo, K. P. Cross, "Classroom assessment techniques," 2nd Ed. San Francisco: CA, Jossey-Bass, 1993.

[7] L.B. Nilson, "Teaching at Its Best: A research-based resource for college instructors," 3rd Ed. San Francisco, CA, Jossey-Bass, 2012.

[8] B. E. Walvoord, "Assessment clear and simple: A practical guide for college instructors," 3rd Ed. San Francisco, CA, Jossey-Bass, 2012.

[9] M. Lanzerotti, C. I. Allen, M. Doroski, C. Medve, M. Seery, L. Orlando, F. Khafizov, "An electrical engineering graduate course sequence in integrated circuits targeted to real-world problems in industry, defense, and security," American Society for Engineering Education Annual Meeting, Paper ID#17791, Columbus, Ohio, June 25-28, 2017.

[10] Richard M. Felder and Rebecca Brent, "Teaching and Learning in STEM: A Practical Guide," New York: New York, Jossey-Bass, 2016. https://educationdesignsinc.com/book/

[11] J. W. Capps, G. A. Lucero, C. S. Gerving, "Thayer 2020(T21): Combining Physics Education Research (PER) and Thayer Method Effects for Advanced and Common Core Physics," Master Teacher Program Paper, 2018.

[12] Amy E. Shell, "The Thayer Method of Instruction at the United States Military Academy: A Modest History and a Modern Personal Account," Problems, Resources, and Issues in Mathematics Undergraduate Studies, 12:1, 27-38, 2007, DOI:10.1080/10511970208984015.

[13] David Sokoloff and Ronald Thornton, "Active Learning with Interactive Lecture Demonstrations," New Faculty Workshop, American Physical Society, American Center for Physics, June 13, 2017.

[14] David Sokoloff and Ronald Thornton, "Active Learning with Interactive Lecture Demonstrations," New Faculty Workshop, American Physical Society, American Center for Physics, June 26, 2018.

[15] Carl Weiman and Sarah Gilbert, "The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science," CBE – Life Sciences Education. 13, 552-569, Fall 2014.

[16] Naki Erdemir, "Determining Students' Attitude Toward Physics Through Problem-Solving Strategy," Asia-Pacific Forum on Science Learning and Teaching, Volume 10, Issue 2, Article 1 (Dec., 2009). Online. Available: https://www.eduhk.hk/apfslt/v10_issue2/erdemir/erdemir2.htm.

[17] Vashti Sawtelle and Sarina Gleason, "How a Physics Class is Changing Student Attitudes for the Better," Michigan State University, 2017. Online. Available: https://msutoday.msu.edu/news/2017/how-a-physics-class-is-changing-student-attitudes-for-the-better/.

[18] Joanne Broggy and George McClelland, "Undergraduate Students' Attitudes Towards Physics After a Concept Mapping Experience," Concept Mapping: Connecting Educators. Proc. Of the Third Int. Conference on Concept Mapping Tallinn, Estonia and Helsinki, Finland 2008. Online. Available: http://cmc.ihmc.us/cmc2008papers/cmc2008-p075.pdf.

[19] Dayton Codebreakers. Online. Available: http://daytoncodebreakers.org.

[20] Jack Kilby, "Turning Potential into Reality: The Invention of the Integrated Circuit," Video, Nobel Lecture 2000. Available: https://www.nobelprize.org/prizes/physics/2000/kilby/lecture/.

[21] Jack Kilby, "Turning Potential into Reality: The Invention of the Integrated Circuit,"

Transcript, Nobel Lecture 2000. Available: https://www.nobelprize.org/uploads/2018/06/kilby-lecture.pdf.

[22] Bill Wilcox, "Bill Wilcox's Interview (2006)," Interview, Atomic Heritage, 2013. Available: https://youtu.be/Yo-spI8TZKA.

[23] Atomic Heritage, Photograph of General Leslie Groves. Available: https://www.atomicheritage.org/sites/default/files/General%20Lesle%20Groves%20notext.jpg.

[24] FLIR, "Airborne Systems," Online. Available: https://www.flir.com/browse/government-defense/airborne-systems/.

[25] South Carolina ETV Commission, "Charles Townes, S.C. Hall of Fame," Video. Online. Available: https://www.knowitall.org/video/charles-townes-sc-hall-fame.

[26] Richard R. Hake. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics. 66, 64 (1998). https://doi.org/10.1119/1.18809.

[27] Lei Bao. Theoretical comparisons of average normalized gain calculations. American Journal of Physics. 74, 917 (2006). https://doi.org/10.1119/1.2213632.

[28] Sam McKagan, Eleanor Sayre, and Adrian Madsen, "Normalized gain: What is it and when and how should I use it?" Online. Available: https://www.physport.org/recommendations/Entry.cfm?ID=93334.

[29] Ken Bain, "What the Best College Teachers Do," 1st Ed. Cambridge, MA: Harvard University Press, 2010.

[30] Schibeci, R. A. and Riley, J. P. (1986), Influence of students' background and perceptions on science attitudes and achievement. J. Res. Sci. Teach., 23: 177-187. doi:10.1002/tea.3660230302.

[31] George Cullum, "Letters of CDT George Cullum USMA 1833," Letters, USMA Library, Papers; 1862-1864.

[32] John Pope, "Letter of CDT John Pope USMA 1842," Letter, USMA Library, Papers; 1838-1877.

[33] Ulysses S. Grant, "Letter of CDT Ulysses S. Grant USMA 1843," Letter, USMA Library, Papers; 1840-1885.

[34] William Dutton, "Letter of CDT William Dutton USM 1846," Letters, USMA Library, Papers; 1842-1862.

[35] James Runcie, “Natural & Experimental Philosophy Notebook of CDT James Runcie USMA 1879,” Notebook, USMA Library, 19th Century Manuscripts.

[36] Charles H. Barth, “Diary of CDT Charles H. Barth USMA 1879,” Diaries and Notebook, USMA Library, Papers: 1879-1914.

[37] George S. Patton, “Letter of CDT George S. Patton USMA 1909,” Letters, USMA Library, Papers relating to dedication of Patton statue at U.S. Military Academy 19 August 1950.

[38] Richard Von Schriltz, “Letter of CDT Richard Von Schriltz USMA 1941,” Letters, USMA Library, Papers: 1934-1969.

[39] Richard Von Schriltz, “Diary of CDT Richard Von Schriltz USMA 1941,” Diary, USMA Library, Papers: 1934-1969.

[40] Henry S. Lowe, “Letters of CDT Henry S. Lowe USMA 1961,” Letters, USMA Library, Papers: 1961-1980.

[41] Curt Esposito, “Letter of CDT Curt Esposito USMA 1963,” Letters, USMA Library, Papers: 1961-1980.

[42] USMA Academic Board, “Academic Board (Staff Records) 1818-1836,” Staff Records, USMA Library, Staff Records.

[43] Joseph Mansfield, “Civil War Telegrams of GEN Joseph Mansfield USMA 1822,” Telegrams, USMA Library, Papers; 1817-1862.

[44] George S. Patton, “World War II Diary of GEN George S. Patton USMA 1909,” Diary, USMA Library, Papers relating to dedication of Patton statue at U.S. Military Academy 19 August 1950.

[45] Leslie R. Groves, “Documents Concerning the Atomic Bomb Mission to Hiroshima, GEN Leslie R. Groves USMA 1918,” Memos, USMA Library, 20th Century Manuscripts.