Reducing The Gender Gap In The Physics Classroom

M. Lorenzo

Catherine Hirshfeld Crouch
Swarthmore College, ccrouch1@swarthmore.edu

E. Mazur

Follow this and additional works at: https://works.swarthmore.edu/fac-physics

Part of the Physics Commons

Let us know how access to these works benefits you

Recommended Citation

https://works.swarthmore.edu/fac-physics/78
Reducing The Gender Gap In The Physics Classroom

M. Lorenzo

Catherine Hirshfeld Crouch
Swarthmore College, ccrouch1@swarthmore.edu

E. Mazur

Follow this and additional works at: http://works.swarthmore.edu/fac-physics

Part of the Physics Commons

Recommended Citation

http://works.swarthmore.edu/fac-physics/78
Reducing the gender gap in the physics classroom
Mercedes Lorenzo, Catherine H. Crouch, and Eric Mazur

Citation: American Journal of Physics 74, 118 (2006); doi: 10.1119/1.2162549
View online: http://dx.doi.org/10.1119/1.2162549
View Table of Contents: http://scitation.aip.org/content/aapt/journal/ajp/74/2?ver=pdfcov
Published by the American Association of Physics Teachers

Articles you may be interested in
Assessing gender differences in response system questions for an introductory physics course
Am. J. Phys. 81, 231 (2013); 10.1119/1.4773562

Reflective discourse techniques: From in-class discussions to out-of-classroom problem solving

Diversity of faculty practice in workshop classrooms

Am. J. Phys. 74, 940 (2006); 10.1119/1.2221345

Investigation of students’ reasoning regarding heat, work, and the first law of thermodynamics in an introductory calculus-based general physics course
Am. J. Phys. 72, 1432 (2004); 10.1119/1.1789161
Reducing the gender gap in the physics classroom

Mercedes Lorenzo
Department of Physics and Division of Engineering and Applied Sciences, Harvard University, 9 Oxford Street, Cambridge, Massachusetts 02138
and IES Universidad Laboral, Avenida de La Mancha, s/n, 02080 Albacete, Spain

Catherine H. Crouch
Department of Physics and Division of Engineering and Applied Sciences, Harvard University, 9 Oxford Street, Cambridge, Massachusetts 02138
and Department of Physics, Swarthmore College, 500 College Avenue, Swarthmore, Pennsylvania 19081

Eric Mazur
Department of Physics and Division of Engineering and Applied Sciences, Harvard University, 9 Oxford Street, Cambridge, Massachusetts 02138

(Received 26 July 2005; accepted 2 December 2005)

We investigate if the gender gap in conceptual understanding in an introductory university physics course can be reduced by using interactive engagement methods that promote in-class interaction, reduce competition, foster collaboration, and emphasize conceptual understanding. To this end we analyzed data from the introductory calculus-based physics course for non-majors at Harvard University taught traditionally or using different degrees of interactive engagement. Our results show that teaching with certain interactive strategies not only yields significantly increased understanding for both males and females, but also reduces the gender gap. In the most interactively taught courses, the pre-instruction gender gap was gone by the end of the semester. © 2006 American Association of Physics Teachers.

[I DOI: 10.1119/1.2162549]

I. INTRODUCTION

In the United States, females are underrepresented in science and technology-related courses and careers and their average scores are lower than males on science tests at the secondary and post-secondary level. This gender gap is also reported at the secondary level in 28 countries in Europe, North America, Asia, Oceania, and the Middle East. Although the gender gap has been closing in most scientific and technological fields, the largest gender disparity in both achievement and professional representation remains in physics.

Extensive research on gender differences in science achievement has been carried out since the 1980s. The results of this research suggest that the following teaching strategies help narrow the gender gap:

1. Integration of everyday experiences and interests that are relevant to both genders into the content and context of instruction.
2. Assessment and use of students’ prior knowledge to construct new knowledge.
3. Interactive environments that enhance cooperation and communication in the classroom among the students and between the students and the instructor.
4. Alternation between group discussion and structured teaching. Females perform better when they are able to articulate their thoughts verbally and males perform better when their learning experience is structured.
5. Activities that decrease competitiveness.
6. Diverse and frequent assessment practices and feedback.
7. Activities that foster students’ understanding.
8. Application of physics to a broader world-view.

Some studies suggest that females benefit especially by the use of active pedagogies. Although active engagement benefits both genders, females tend to learn more when they express ideas in words through discussion, whereas males prefer working independently.

The interactive engagement (IE) methods used in this study (Peer Instruction, the Tutorials in Introductory Physics, and cooperative quantitative problem-solving activities) make use of many of the strategies listed above [particularly strategies (3)–(7)]. We therefore investigated if these teaching methods narrow the gender gap in the large calculus-based introductory physics course for non-majors at Harvard University.

II. METHODOLOGY

The introductory calculus-based physics course for non-majors was taught at Harvard from 1990 to 1997 (no data were collected in 1992). This course, which covers Newtonian mechanics, meets twice a week in a large lecture hall for a total of 3 h of instruction and once a week for 1 to 2 h in smaller sections of 15–20 students directed by teaching assistants. During the seven years of the study, the average enrollment in the course was 202; the student gender ratio in the course averaged 1.7 (male/female).

A. Teaching approaches

The teaching approach evolved from traditional lectures to a highly interactive teaching style. In 1990 both the lectures and the sections were taught using a traditional lecture format. In 1991 traditional lectures were replaced by Peer Instruction (PI). Peer Instruction modifies the traditional lecture by alternating between short (10–15 min) mini-lectures and conceptual questions discussed by students in small groups to directly address conceptual difficulties during class.

http://aapt.org/ajp © 2006 American Association of Physics Teachers
This article is copyrighted as indicated in the article. Reuse of AAPT content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 

solving activities similar to those developed by Heller
workshop is devoted to reinforcing the students' problem-
size conceptual reasoning and hands-on activities rather than
apply them to real-world situations. The second half of the
under the supervision of teaching assistants, the
in Ref. 19.
Although the lectures from 1990 to 1995 actively involved
students once Peer Instruction was implemented, the weekly
1.5-h section meetings consisted primarily of traditional pre-
sentations by a teaching assistant to students seated in rows.
In 1996 these traditional sections were replaced with weekly
2-h workshops during which students worked in groups of
three or four seated around tables. During the first hour of the
workshop, students completed the Tutorials,20 which empha-
size conceptual reasoning and hands-on activities rather than
standard quantitative problem solving and provide a struc-
tured opportunity for students to discuss concepts with one
another. Under the supervision of teaching assistants, the Tu-
torials help the students construct conceptual models and
apply them to real-world situations. The second half of the
workshop is devoted to reinforcing the students’ problem-
solving skills through cooperative quantitative problem-
solving activities similar to those developed by Heller et al.22
Table I summarizes the teaching approaches used and clas-
sifies the courses studied into three groups: traditional (T),
partially interactive (IE1), and fully interactive (IE2).
Five instructors taught these courses; one of the instructors
used all three approaches in different years, and others used
only one or two of the three approaches. We find consistent
results for each approach regardless of the instructor. Conse-
quently, we conclude that the observed changes in students’
performance are not caused by changes in the instructor, but
rather due to the variation in teaching strategy.

### B. Assessment methods and data collection

To investigate how interactive teaching methods affect the
gender gap in conceptual understanding, we used the Force
Concept Inventory (FCI).23 This test is widely used to assess
students’ understanding of Newtonian mechanics in introdus-
tory physics courses and to evaluate the effect of changes in
instructional practice.24 Students were given 45 min to com-
plete the test, once at the beginning of the semester (pretest)
and again three months later after instruction in mechanics
was completed (posttest). No pretest data are available for
the traditionally taught course.

Between 1990 and 1994 we used the original version of
the test consisting of 29 questions. In 1995, the test was
revised to eliminate ambiguities. Starting in 1995, we used
the revised version, which contains 30 questions. The two
versions of the test have 27 questions in common, although
some of these questions were slightly worded. Because the
assessment instrument changed slightly during this study, we
analyzed the FCI scores by scoring all questions on each
version of the test and by only scoring the overlapping 27
questions. The two analyses yield similar results, indicating
that the revision of the FCI in 1995 did not affect the results.
The statistical analysis presented in this paper is based on
the complete set of questions for both test versions.

In addition to the FCI, we also examined scores on the
Mechanics Baseline Test25 (MBT) which we administered
just before the final exam. These scores are tabulated in the
online supplementary materials.26 The average gender gap in
the MBT scores is less than or similar to the gap found on
the FCI posttest for all groups surveyed. Although there is a
small post-instruction gender gap for all three groups, the
gap in the MBT scores is smallest for the IE2 group (4.8%).
In addition, the IE2 group shows the highest MBT scores of
the three groups.

We analyzed data only from students who completed the
FCI pretest (for IE courses), the FCI posttest, and the MBT,
for a total of 1048 students. We focused our analysis on the
FCI rather than the MBT, because the FCI directly probes the
effects of instruction, was given as a pretest and a posttest,
while the MBT was given only as a posttest. Because the
gradable scheme for the course and the nature of the final
examinations changed from year to year, the data from ex-
aminations and final grades are not comparable from year to
year and were therefore omitted from this study.

### III. RESULTS AND DISCUSSION

Table II provides the average FCI pretest score $S_i$ and
posttest score $S_f$ for males and females, with the corre-
sponding gender gap $(S^M-S^F)$ and $p$ values. The average pretest
scores for both males and females in the IE courses remained
approximately constant over the duration of the study; the
year-to-year variations are not statistically significant. There-
fore, the differences between groups observed on the posttest
scores can be attributed to differences in instruction rather
than different student backgrounds. In addition, the pretest
gender gap, $S^M-S^F$, is statistically significant for each course.

Table II shows that the scores for both genders increase
after instruction. In addition, the posttest scores for both gen-
sers increase as the level of interactive engagement increases
from T to IE1 and then IE2. Both male and female students in
the T course score lower than the students in the IE groups
on the posttest. According to a study by Henderson et al.,27
administering the pretest does not bias posttest results and so
the low posttest scores for the T course cannot be attributed
to the absence of a pretest.
This shows that the higher the level of interactive engagement in the course, the smaller the gender gap is after instruction.

To further evaluate the impact of each of the three teaching approaches on the students’ performance, we also calculated the class average normalized gain $g = (\langle S_f \rangle - \langle S_m \rangle) / (100 - \langle S_m \rangle)$ from the FCI scores. The normalized gain accounts for differences in the pretest score by determining what fraction of the total possible gain from pretest to posttest is achieved. The average of pretest scores for the IE courses was used as the T course pretest. Figure 2 shows that $g$ increases for both genders as the level of interactive engagement in the course is increased. For the IE1 and IE2 groups, the difference in the normalized gain between males and females is not statistically significant; in the IE2 group, both genders achieve the same high normalized gain (0.70 for males and 0.71 for females). The data in Fig. 2 are tabulated in the online supplement along with the $p$ values. We were unable to determine if the gender gap for the T group is statistically significant because the T group did not take the pretest.

According to Hake’s normalized gain classification, both male and female students in the IE2 group fall into the high-gain category, $g \geq 0.7$. In contrast, females in the T course
fall into the low-gain category, \( g < 0.3 \), while the male students in the T course are at the low end of the medium-gain category, \( 0.3 \leq g < 0.7 \). Although the normalized gains in the IE groups are almost the same for both genders, females achieve higher absolute gains than males because their pre-test scores are lower than those of the males. The data in Fig. 2 clearly show that increasing the level of interactive engagement during instruction not only benefits all students but also helps equalize the normalized gains of the two genders.

We now analyze how different methods of instruction affect the number of students who achieve very low or very high scores on the FCI. The authors of the FCI consider a score below 60% to indicate no real understanding of Newtonian mechanics, and a score above 85% as indicating mastery of Newtonian mechanics.\(^{28}\) We classified students scoring less than 60% on the FCI as “low scoring” and students scoring above 85% as “high scoring.” We found no significant variation in pretest percentages from year to year for each gender, so we compared the average of all IE pretest data to the posttest percentages of the three groups.

Before instruction, the percentage of low-scoring females is twice that of the males, as shown in the upper panel of Fig. 3. Almost half (43%) of the females did not have a basic understanding of mechanics at the beginning of the term. In contrast, the percentage of females within the high-scoring category is only one-third that of the males (10% in comparison to 27%).

After instruction, the situation for female students improved dramatically in the interactive engagement courses. The percentage of females remaining in the low-scoring category after instruction was only 4.4% for the IE1 group—a tenth of those who were in the low-scoring category initially—and there were no low-scoring females in the IE2 group after instruction. Improvement in the T course was less dramatic; 23% of female students were still in the low-scoring category, half as many as earned low scores on the pretest. In all three groups, the number of low-scoring males dropped to only a few percent (on average 2%), with no significant differences between groups.

Three features of the data for high-scoring students, shown in the lower panel of Fig. 3, are noteworthy. The percentage of high-scoring female students before instruction is small (10% for females in comparison to 27% for males). Although the percentages of high-scoring students increased somewhat after traditional instruction for both genders, it increased more after interactive instruction. In the IE2 group the female students increased their scores so much that none of them remained in the low-scoring category after instruction, and the difference between the percentages of high-scoring males and females is not statistically significant. These results show that interactive engagement courses more effectively reduce the percentage of low-scoring females and increase that of high-scoring females than traditionally taught courses.

The reduction or elimination of the gender gap in mechanics in the interactive courses is due to the remarkable improvement in the performance of female students with no observed loss of achievement among the male students. Male students also achieve at a higher level with interactive engagement instruction than with traditional instruction.

We attribute the observed reduction of the gender gap to the use of Peer Instruction, the Tutorials,\(^{20}\) and cooperative quantitative problem-solving activities. These instructional methods give students opportunities to interact and explain their ideas during both lecture and section, providing frequent feedback to students on their understanding through the conceptual questions and tutorials, alternating between structured teaching and peer discussion, emphasizing conceptual reasoning, promoting collaboration among peers, and creating a less competitive classroom culture. Our results confirm that these instructional methods help reduce the gender gap in physics understanding. We hypothesize that teaching in this fashion provides a learning environment that is good for both male and female students.

**IV. CONCLUSIONS**

Our study demonstrates that interactive engagement effectively reduces the gender gap in physics performance. Although both genders benefit and achieve similar high normalized gains, females improve their performance most, and overcome a considerable pre-instruction gender disparity. As the attention to conceptual understanding and the level of classroom interactivity and collaboration is increased, the gender gap decreases; in the fully interactive courses, it is entirely eliminated. By creating a classroom environment that benefits both genders, the teaching approach described here improves student understanding and narrows the gender gap in physics education.

**ACKNOWLEDGMENTS**

The authors would like to thank Dr. Veronica McCauley, Jessica Watkins, Dr. Jessica Rosenberg, Dr. Martin Vogt, and...
Iva Maxwell for input on the manuscript; Professor Steve Wang for advice on statistical analysis; and Dr. Suvendra Nath Dutta and Vijay Salagala for technical support. ML gratefully thanks EM and the Division of Engineering and Applied Sciences at Harvard University for the opportunity to visit, and the Consejería de Educación de Castilla-La Mancha (Spain) for its generous support during her leave of absence. Her deepest gratitude goes to her brother Raimundo José for his support, encouragement, and help in all her projects and dreams. This work was supported by a grant from the National Science Foundation.

Electronic mail: ccrouch1@swarthmore.edu


E. Mazur, Introductory Physics (to be published).


See EPAPS Document No. E-AIPiAS-74-003603 for tables of the Mechanics Baseline Test scores and Force Concept Inventory gains and normalized gains. This document can be reached via a direct link in the online article’s HTML reference section or via the EPAPS homepage (http://www.aip.org/pubservs/epaps.html).


Mercedes Lorenzo, Catherine H. Crouch, and Eric Mazur

Citation: American Journal of Physics 74, 940 (2006); doi: 10.1119/1.2221345

View online: http://dx.doi.org/10.1119/1.2221345

View Table of Contents: http://scitation.aip.org/content/aapt/journal/ajp/74/10?ver=pdfcov

Published by the American Association of Physics Teachers

Articles you may be interested in

Comment on “Quantum mechanics of the 1/x 2 potential,” by Andrew M. Essin and David J. Griffiths [Am. J. Phys. 74 (2), 109–117 (2006)]
Am. J. Phys. 75, 953 (2007); 10.1119/1.2742401

Am. J. Phys. 74, 841 (2006); 10.1119/1.2218360

Am. J. Phys. 74, 743 (2006); 10.1119/1.2206574

Am. J. Phys. 74, 558 (2006); 10.1119/1.2186691

Reducing the gender gap in the physics classroom
Am. J. Phys. 74, 118 (2006); 10.1119/1.2162549
Erratum: “Reducing the gender gap in the physics classroom”
[Am. J. Phys. 74 (2), 118–122 (2006)]

Mercedes Lorenzo
IES Universidad Laboral, Avenida de La Mancha, s/n, 02080 Albacete, Spain
Department of Physics and Division of Engineering and Applied Sciences, Harvard University,
9 Oxford Street, Cambridge, Massachusetts 02138

Catherine H. Crouch
Department of Physics and Division of Engineering and Applied Sciences, Harvard University,
9 Oxford Street, Cambridge, Massachusetts 02138
Department of Physics, Swarthmore College, 500 College Avenue, Swarthmore, Pennsylvania 19081

Eric Mazur
Department of Physics and Division of Engineering and Applied Sciences, Harvard University,
9 Oxford Street, Cambridge, Massachusetts 02138

(Received 5 June 2006; accepted 8 June 2006)
[DOI: 10.1119/1.2221345]

We regret to report that Ref. 4 from our recent article is cited incorrectly. The correct reference is Hake, R.R., “Relationship of Individual Student Normalized Learning Gains in Mechanics with Gender, High-School Physics, and Pretest Scores on Mathematics and Spatial Visualization” (2002), available online at (http://www.physics.indiana.edu/~hake/PERC2002h.Hake.pdf).

*Electronic mail: ccrouch1@swarthmore.edu

Recording Aneroid Barometer. For accurate determination of the local atmospheric pressure nothing beats the vertical Torrecllian barometer. However, the recording aneroid barometer is a useful adjunct to the physics laboratory. Here the top of a sealed metal container with flexible sides moves up and down in response to changes in the surrounding air pressure. A mechanical multiplier is used to move the ink-tipped pen up and down across a sheet of paper on a slowly-revolving drum. This early twentieth century barometer was made in France and is in the Greenslade Collection. (Photograph and Notes by Thomas B. Greenslade, Jr., Kenyon College)