Two Methods in Teaching Introductory Physics, with Emphasis on the Effect in Gender Performance

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Inter-active pedagogy

Do not then train youths to learning by force and harshness, but direct them to it by what amuses their minds so that you may be better able to discover with accuracy the peculiar bent of the genius of each.

Plato

The object of education is to teach us to love beauty.
Female students are underrepresented in physics
Girls do better in science classes taught interactively
We test the effect of teaching methods on girls scores
We analyze data for 200 students taking 200 level physics
Goal: promote female success and narrow the gender gap
both in representation and in performance

ABSTRACT
Girls choose biology and chemistry over physics
Literature

- Girls choose biology and chemistry over physics
- First college year was identified as “leak in the pipeline”
Girls choose biology and chemistry over physics
First college year was identified as “leak in the pipeline”
Large gender disparity both in gender & representation
Typical female population in introductory physics
  • 20% in algebra-based introductory physics courses
  • 10% in calculus-based introductory physics courses
Enhancing the female success – difficult endeavour
- Warm and supportive environment
- Innovative subjects
- Interactive pedagogy
- Cooperative (non-competitive) spirit
- A friendly and inclusive approach benefits all students, but especially women
1. Awareness
   a. High expectations on both
   b. Balance cooperative & competitive activities
Female Friendly Strategies

1. Awareness
   a. High expectations on both
   b. Balance cooperative & competitive activities

2. Strategies
   a. Use single-sex small groups
   b. Provide female role model
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3. Attitudes
   a. Encourage can-do attitudes
   b. Encourage girls to take risks
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3. Attitudes
   a. Encourage can-do attitudes
   b. Encourage girls to take risks

4. Other factors
   a. Personal confidence
   b. Teacher’s attitudes
Gender Differences Research

1) No sex-related differences – the social aspect
   a. Physics is an essential masculine avocation
   b. Women are less able/interested in physics

Example: modified Fennema-Sherman attitude scale
   • Women should ask a man for help to solve a physics problem
   • Men are naturally better than females in physics
   • Women who enjoy studying science are a little strange
   • I would expect a woman physicist to be a forceful person
Gender Differences Research

2) Basic gender differences on learning – psychology
   - Male: deductive, rigorous, structured and axiomatic,
   - Female: inductive, experiential, creative and intuitive

Causal attributions
   - Males: success = own ability, failure = lack of effort,
   - Females: success = luck, failure = lack of ability
   - Males: separate learning = need for proof
   - Females: connected learning = need for connection

Critical variables for attributional retraining:
   - Confidence
   - Usefulness
   - Attitudes
Introduction

• Question: Can teaching methods influence female performance?
• Validating the effect of innovative teaching is difficult
• No “silver bullets” – more like puzzle pieces falling into place
• Filtering out clear gender distinctions is complicated
Introduction

• ”General stuff that makes physics fun, especially for people who do not like math” (female student).
Introduction

• “General stuff that makes physics fun, especially for people who do not like math” (female student).
• Methods:
  1. The lecture-based method, enhanced with multimedia and online homework
  2. The active learning labs method

We detect gender differences in the major choice, and both in the overall and broken down (homework, tests, attendance, etc) grades
Method 1

THE LECTURE-BASED METHOD

- Algebra-based course PHY201 – suitable for pre-med track
- Textbook enhanced with
  - integrated multimedia resources,
  - PhysicsNow online problem solving and tutorial
  - ExamView test preparation software
- Structure (3h/week):
  - 2 h Power-Point presentations enhanced with short movies
  - 1 h interactive problem-solving–work in small groups
- Examination
  - 3 tests (2 partial one final) with 10 multiple choice problems
  - Online homework and attendance
THE ACTIVE LEARNING METHOD

- Discovery-based lab course PHY202, corequisite with PHY201
- Students benefit:
  - Construct their own models of physical phenomena
  - Acquire a progressive understanding of physics concepts
  - Perform better in groups of 2-4 people
- Structure (2h/week):
  - 14 labs based on guided activities enhanced by computer use
  - In-class review of difficult concepts (projectile motion, circular motion)
- Examination:
  - In-lab activity (Incomplete/Partial/Complete grading)
  - 2 partial tests, each from 7 labs, with 10 problems
  - Homework & report
PROF. THOMAS WILSON
1. Course PHY 202
   Description: physics labs based on the active learning discovery labs method.
2. Course: PHY 211
   Description: calculus physics lecture enhanced with:
   - SmartWork online homework
   - Peer instruction in-class conceptual questions

ASSIST. PROF. XIAOJUAN FAN
3. Course PHY 203
   Description: algebra physics lecture enhanced with:
   - WebCT online homework
   - Unannounced 10 minutes pop-quizzes at the beginning of a class.
Author's students

22 FEMALES OUT OF 68 – 32%
PHY201 Gender Number Percentage

20 FEMALES OUT OF 58 – 34%
PHY202 Gender Number Percentage

[Pie charts showing gender distribution for PHY201 and PHY202]
Dr. Wilson's students

<table>
<thead>
<tr>
<th>Course</th>
<th>Gender</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHY202 Wilson</td>
<td>Female</td>
<td>6</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHY 211 Wilson</td>
<td>Female</td>
<td>5</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LARGE FEMALE PERCENTAGE

- Unexpected result!
- Could be because the course contains optics & modern physics (life-related), and no mechanics (technical)
- But PHY203 requires PHY201!

15 FEMALES OUT OF 31 – 42%

PHY203 Female-Male Number Percentage
Author's PHY201 class

68% BIOLOGY; 22% CHEMISTRY; 5% ENG/TECH; 5% OTHERS

PHY 201 Female Majors Distribution

36% BIOLOGY; 7% CHEMISTRY; 50% ENG/TECH; 7% OTHER

PHY 201 Male Majors Distribution
Author's PHY202 class

75% BIOLOGY; 15% CHEMISTRY; 5% ENG/TECH; 5% OTHER

PHY202 Female Majors Distribution

34% BIOLOGY; 21% CHEMISTRY; 42% ENG/TECH; 3% OTHER

PHY202 Male Majors Distribution
Author's Histogram PHY201

Girls scores were mostly average (C) and high (A) ends.

Boys scored in the lower (D) and higher (A) ends.

PHY201 Female Letter Grade

PHY201 Male Letter Grade
GIRLS SCORED EQUAL NUMBER OF B AND A GRADES

BOYS SCORED MORE B GRADES

PHY202 Female Letter Grade

PHI202 Male Letter Grade
DIFFERENCE IN GIRLS C AND BOYS D PERCENTAGE

A HIGHER PERCENTAGE OF BOYS RECEIVED B

PHY201 Grade Percentage

PHY202 Grade Percentage
Visible male/female differentiations in: exams, homework, participation, attendance final, Girls obtained higher grades, especially on attendance and homework.
Comparison

Less visible male/female differentiations. Girls obtained higher grades, excepting attendance. The fact that a missed lab had to be recuperated was a bigger incentive for boys!
Dr Wilson's Grade Percentage

DIFFERENCE IN THE HIGHER & LOWER ENDS OF THE GRADES

PHY202 Wilson Grade

<table>
<thead>
<tr>
<th>Grade</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>40</td>
</tr>
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</table>

PHY211 Wilson Grade

<table>
<thead>
<tr>
<th>Grade</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>40</td>
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</tr>
<tr>
<td>C</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>
Comparison Dr. Wilson

GIRLS OUTPERFORMED BOYS

PHY202 Number Grade

BOYS OUTPERFORMED GIRLS, NOT AT PEER INSTRUCTION & HOMEWORK

PHY211 Number Grade

- **Total**
- **Exam 1**
- **Exam 2**
- **Exam 3**
- **Exam 4**
- **Peer Inst**
- **ST Work**
- **Final**

Female
Male
GIRLS SCORES WERE MOSTLY LOW (D) AND HIGH (B)

PHY203 Female Letter Grade

GIRLS SCORES WERE MOSTLY AVERAGE (C) AND HIGH (B)

PHY203 Male Letter Grade
Comparison Dr. Fan class

VISIBLE DIFFERENCE IN THE AVERAGE GRADES

GIRLS OUTPERFORMED BOYS EXCEPTING POP-QUIZ GRADES

PHY203 Percentage Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PHY203 Number Grade

<table>
<thead>
<tr>
<th>Component</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hwork</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attend</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Gender/major</th>
<th>BIOLOGY</th>
<th>CHEMISTRY</th>
<th>ENG/TECH</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>68% - 75%</td>
<td>22% - 15%</td>
<td>5% - 5%</td>
<td>5% - 5%</td>
</tr>
<tr>
<td>Male</td>
<td>32% - 34%</td>
<td>7% - 21%</td>
<td>50% - 42%</td>
<td>7% - 3%</td>
</tr>
</tbody>
</table>

### Gender distribution

<table>
<thead>
<tr>
<th>Gender/class</th>
<th>PHY201</th>
<th>PHY202</th>
<th>PHY211-W</th>
<th>PHY202-W</th>
<th>PHY203-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>32%</td>
<td>34%</td>
<td>18%</td>
<td>33%</td>
<td>48%</td>
</tr>
<tr>
<td>Male</td>
<td>68%</td>
<td>66%</td>
<td>82%</td>
<td>67%</td>
<td>52%</td>
</tr>
</tbody>
</table>

### Average grades by gender

<table>
<thead>
<tr>
<th>Gender/class</th>
<th>PHY201</th>
<th>PHY202</th>
<th>PHY211-W</th>
<th>PHY202-W</th>
<th>PHY203-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>84.75</td>
<td>86.88</td>
<td>75.31</td>
<td>84.17</td>
<td>79.0</td>
</tr>
<tr>
<td>Male</td>
<td>79.10</td>
<td>84.69</td>
<td>78.20</td>
<td>80.17</td>
<td>72.1</td>
</tr>
</tbody>
</table>
Women tend to steer away from technology and are more attracted towards the life sciences.
The uncommon choices revealed parents influence.
Success in women representation: 33% in algebra physics, 18% in calculus.
Girls outperformed boys overall, with higher differences in homework, attendance, and peer-instruction, in which the outcome is most closely tied to effort.

Findings
Female students outperformed male students on average in all but one of the courses (calculus PHY211). The standard deviation of females’ grades is consistently smaller than males’.
Female students outperformed male students on average in all but one of the courses (calculus PHY211).

The standard deviation of females’ grades is consistently smaller than males’.

Correlation percentage - performance for girls:
- girls were 48% and outperformed boys the most in PHY203
- girls represent only 18% and underperformed boys in PHY211

Girls have not dropped out of physics in larger numbers than the boys by the second course PHY203.

Possible explanations:
- Peer effect at work
- What attracted girls in the first place also lead them to perform better
Conclusions

- Females at Marshall University already outperform their male counterparts in the non-major courses!
- Active-learning labs seem to give good results, but traditional lectures have bigger effect on the relative grades of boys and girls than active-learning lectures
- What seem to matter is students’ motivation, which may come from their choice of major: most women were pre-med and more driven to succeed.
- More data is needed to explain the PHY203 results
- What teaching method motivates students most?
References

Acknowledgements

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Einstein

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.

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