

Effects of Lab Group Sex Composition on Physics Learning

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The aim of this study was to investigate the effects of the gender composition of university physics laboratory groups on student self-efficacy and quiz performance. Students from a Chinese university was chosen and subdivided into two groups, which were assigned either same-sex or coed laboratory teams while executing identical laboratory activities and instruction. Assessments were carried out prior to instruction and at the end of one semester. Students' self-efficacy and scores on laboratory quizzes were assessed. In this study, no statistically significant differences for the male students' self-efficacy gain and average laboratory quiz scores in the two types of team organization were found. In contrast, the female students' self-efficacy gain and lab quiz mean scores from same-sex teams were higher than ones from coed teams. So it delivered some messages to physics instructors and physics education researchers: Single-sex lab team education is beneficial for female students.

Keywords: gender education, physics laboratory, self-efficacy, university physics

INTRODUCTION

Single-Gender vs. Mixed-Gender Education

Boys and girls learn differently. Concerns about gender differences in science education emerged in the 1970s and 1980s (Fennema & Sherman, 1977), and remains a predominant issue in the beginning of the 21st century (Fuselier & Jackson, 2010; Shi, 2012). From preliminary findings, researchers have reported positive outcomes from the single-gender classroom settings in schools. Discovery-based learning, collaborative work in groups, and emphasis on cooperation over competition are more effective teaching methods for girls' learning styles (Strand & Mayfield, 2002). Teachers need to embrace the different styles of learning to ensure all students' needs are being met. Gender helps create a set of environmental expectations and transactions unique to boys or girls. These differences in gender makeup indicate that differential learning environments could be

advantageous for boys and girls (Costa, Terracciano, & McCrae, 2001; McFarland et al., 2011). Males and females in mixed-gender settings may feel inadequate and unprepared for the material being taught because of these social differences, thus making single-gender education an option for an alternative learning environment (Kommer, 2006).

Some proponents argue that single-sex education is beneficial for girls because teachers' and peers' sexist attitudes and behaviors interfere with girls' learning in coeducational environments (Sadker & Sadker 1994). They note, for example, that boys tend to seek out and receive the majority of teacher attention in coeducational classes, especially in stereotypically masculine subjects such as mathematics and science. Classrooms that do not include males are thought to be more supportive of girls' academic achievement in counter-stereotypic domains such as math and science than classrooms that include males (Shapka & Keating 2003). Proponents of same-sex education argue that an all-female setting may help girls overcome gender stereotypes and provide them with a more suitable learning environment. Therefore, they maintain, same-sex education can help to reduce the gender gap. According to previous research, in Israel, as in the United States (Miller, Slawinsky Blessing & Schwartz 2006), physics is perceived as "masculine" subjects, a central assumption behind arguments for same-sex

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State of the literature

- The preliminary studies showed positive outcomes from the single-gender classroom settings in schools.
- Classrooms that do not include males are thought to be more supportive of girls' academic achievement in science than classrooms that include males.
- However, there are few studies about gender effects in the laboratory setting.

Contribution of this paper to the literature

- This study provides an investigation of the relationships between laboratory group gender composition and self-efficacy, lab quiz performance in a Chinese university
- No single research on the topic has been reported before in China, it should be an important supplement to this for the international compare education
- Female students in single-sex groups are more likely to achieve high scores on self-efficacy and lab quiz performance than their counterparts in coed groups; the similar effect for male students is not found

schooling is that an all-female environment may diminish the impact of masculine stereotypes. In their reviews of research on same-sex schooling, Mael (1998) conclude that girls in all-female settings express more positive attitudes to subjects such as physics, which they perceive as less masculine than do girls at coeducational schools.

The domain of group dynamics during college problem solving has been examined by Heller (Heller & Hollabaugh, 1992; Heller, Keith & Anderson, 1992) and by the Department of Physics Education Research at the University of Minnesota. The focus of their research was to increase problem solving abilities in the physics student by cooperative activities. The study examined how the gender makeup of the team affected the learning of the members. The students' written solutions were also examined for correctness and completeness. The results of this study indicated that same-sex teams performed well, as did female majority teams. However, in teams of two males and one female, the females were at a disadvantage, as measured by their written solutions. This was not an experimental study, however, and the results are not analyzed quantitatively. Harskamp, Ding & Suhre (2008) did an experimental study with random assignment of the high school physics students to same sex or mixed gender problem solving dyads. The study then measured the types of communication used by the student during problem solving and measured the

student problem solving skills. The results of this study showed that in same sex dyads females used good problem solving strategies. In mixed gender dyads the females exhibited different communication types and performed poorly on the problem solving activities. However he did not calculate an effect size, so the significance of the gender difference was not reported.

These studies suggest the presence of a gender difference in cooperative groups, but do not extend into the university physics laboratory setting, where equipment manipulation is a significant proportion of the activities. Lorenzo, Crouch & Mazur (2006) compared the gender gap present in traditionally taught physics lectures and laboratories to the gender gap present when active pedagogies are used in the lecture, while Tutorials (inquiry based) and interactive problem solving techniques are used in the laboratory. The results of the study were very positive in that reformed teaching techniques significantly reduced the gender gap compared to the traditional pedagogies. Unfortunately the study did not separate the effects of the laboratory pedagogies from the lecture pedagogies. Further studies would be required to separate these two effects.

Research Focus

Gender equity studies have suggested that same-sex teams in the university physics laboratory would be advantageous to women, but the effects upon self-efficacy and performance have not been investigated. While the positive correlation between self efficacy beliefs and performance in physics classes has been recognized and characterized. Yet little is known about gender effects of laboratory team organization on self-efficacy and the performance of the university student in the physics laboratory environment, especially for a Chinese university. We all know Chinese Confucian Heritage Cultures (CHC) environment which is different from western countries (Watkins & Biggs, 1996; Shi, 2012). So the study conducted in China is much needed. The purpose of this study is to investigate the relationships between laboratory-group gender composition and self-efficacy, lab quiz performance in a Chinese university and to find answers to these questions as follows: 1. Does gender composition of the laboratory team in a university physics laboratory influence students differently on the change of their self-efficacy? 2. Does gender composition of the laboratory team in a university physics laboratory influence students differently on the change of their performance on the laboratory quiz?

METHOD

General Background of Research

This study is designed to investigate the relationships between laboratory-group gender composition and self-efficacy, quiz performance. A student population from a Chinese university (University of Science and Technology Liaoning) was chosen and subdivided into two groups, which were assigned either same-sex or coed laboratory teams while executing identical laboratory activities and instruction. Assessments were carried out prior to instruction and at the end of one semester.

Sample of Research

Two hundred and seventeen students majored in Biological Engineering, communication engineering and Materials Science and Engineering who were taking the university physics experiment courses (PHYS 1302) offered by the department of physics at the University of Science and Technology Liaoning (USTL) during the autumn semester of 2013 participated in the study. PHYS 1302 is a 3-credit physics experiment course for students majoring in engineering. There were 7 students that did not complete one of the assessments, leaving a blank in their data. At last, 210 students completed the survey. One hundred and twenty participants (57%) were male and 90 participants (43%) were female. The number and percentage of participants by gender are presented in Table 1.

Instrument and Procedures

Self-efficacy: The goal of this instrument is to estimate the students' self-efficacies, specifically in the physics laboratory. The student's self-efficacy was measured using the science self-efficacy questionnaire developed and validated by Smits (1996). The original questionnaire was developed to estimate high school students' self-efficacy in science. As such it had 28 items and measured self-efficacy in three science domains (Biology, Chemistry, Physics) as well as science laboratory self-efficacy. The students respond with a Likert scale of zero to nine, with zero meaning no certainty, and nine meaning absolutely certain. The total self-efficacy score was an average of the individual item scores, yielding a number between zero and nine. Given that the focus of this paper is on the lab experience, the lab self-efficacy (8 items) will be used when testing the hypotheses. From the original questionnaire, several items in the laboratory section were revised to make the question valid for a university level physics laboratory (see Appendix). The wording of 'Handling laboratory chemicals' was changed to ' setting up the

physics laboratory equipment.' The wording of 'Lighting a laboratory (Bunsen) burner' was changed to 'Wiring together the circuit'. The wording of 'Using a microscope' was changed to 'Using the EXCEL or other software to plot and then run a regression on the data.' Finally, 'Winning a science fair award for a biology project' was changed to 'Winning a student report presentation award.' Using the data collected from the start of semester self-efficacy pre-test ($n = 217$), a Cronbach's alpha was calculated for the modified questionnaire, yielding $\alpha = 0.87$ for the laboratory section showing acceptable internal consistency for the questionnaire. The lab self-efficacy gain was calculated as the post-test score minus the pre-test score. This was an indication of how much the student's self-efficacy had increased during the semester. It was possible for the student's self-efficacy to decrease, yielding a negative number for the gain. The self-efficacy gain could then vary from -9 (lost all self-efficacy) through zero (no change) up to +9 (large gain in self-efficacy).

Laboratory Quiz: The physics laboratory quiz was developed by the Physics laboratory at University of Science and Technology Liaoning (USTL). It consisted of two parts: First the student was asked to set up the laboratory equipment and record some data. This part of the quiz checked the student's manipulation skills. Second the student was asked to analyze/plot data. The purpose of this section was to verify the student could analyze/plot the data, perform appropriate calculations, and interpret the results. The laboratory quiz was taken as an individual. This is in contrast to the laboratory activities, which the student had performed as part of a team. The prototype quizzes were written by the author and were designed to mirror laboratory activities the students had previously performed as a team member and had received feedback. The prototype quizzes were reviewed by all of the instructors of the laboratory sections to confirm content validity.

The single difference between the treatment group and the control group is that the treatment group was assigned same sex laboratory teams while the control group was assigned to coed teams. Students from all sections received lecture instruction from the same instructional staff. Students from all sections received precisely the same assignments, laboratory activities, and laboratory quizzes, regardless of laboratory section. Quizzes and laboratory reports were graded consistently for all sections. The laboratory instructors regularly communicated to ensure consistency in grading and administration of the laboratories. The laboratory exercises were traditional lab activities where the students follow the instructions, collect and analyze data, then write a lab report. The group sizes are presented in table 2. The groups consisted of dyads; in total, there were 22 all of female groups, 37 all male groups, and 45 mixed groups ($N = 104$ groups).

Table 1. The number of participants by gender and majors

Major	Male	Female	Total
Biological Engineering	41	25	66
Communication engineering	38	35	73
Materials Science and Engineering	41	30	71
Total	120	90	210

Table 2. Group sizes

	Coed Teams	Same-Sex Teams	Total
Male	45	75	120
Female	45	45	90
Total	90	120	210

Table 3. The means, standard deviation and the t-test results of the self-efficacy gain

Gender	Team	Mean	SD	Differ	<i>t</i>	<i>df</i>	<i>p</i>
Male	Same-sex	0.86	0.05	0.01	0.97	99	0.34
	Coed	0.87	0.05				
Female	Same-sex	1.78	0.07	0.94	66.15	86	0.00
	Coed	0.84	0.06				

Table 4. The means, standard deviation and the t-test results of performance on the laboratory quiz

Gender	Team	Mean	SD	Differ	<i>t</i>	<i>df</i>	<i>p</i>
Male	Same-sex	76.69	4.65	0.22	0.26	88	0.79
	Coed	76.47	4.38				
Female	Same-sex	77.78	3.77	2.31	3.15	85	0.00
	Coed	75.47	3.15				

Data Analysis

Descriptive statistical procedures such as means and standard deviations and inferential statistical procedures such as t-test were used to determine the effects of two types of team organization (same-sex and coed) on the self-efficacy gain and lab quiz scores. All statistical procedures were performed with the Statistical Package for the Social Science (SPSS version 19.0). The statistical significance in this study was set at a 0.05 level with two-tail tests.

RESULTS

Does gender composition of the laboratory team in a university physics laboratory influence students differently on the change of their self-efficacy? When comparing with t-tests to determine whether there were differences on the self-efficacy gain between two types of team organization participants, no significant differences were found among the male participants, however, the self-efficacy gain for female participants in same-sex teams was higher than the ones in coed teams. The means, standard deviation, and the t-values of the self-efficacy gain compared are presented in the Table 3.

Does gender composition of the laboratory team in a university physics laboratory influence students differently on the change of their performance on the laboratory quiz? The t-test indicated no statistically significant for the male students' average laboratory quiz scores in the two types of team organization. In contrast, the female students' mean scores from same-sex teams were higher than the mean scores from coed teams. The means, standard deviation, and the t-values of performance on the laboratory quiz are displayed in Table 4.

DISCUSSION AND CONCLUSION

In this study, no statistically significant differences for the male students' self-efficacy gain and average laboratory quiz scores in the two types of team organization were found. In contrast, the female students' self-efficacy gain and lab quiz mean scores from same-sex teams were higher than ones from coed teams. So it delivered some messages to physics instructors and physics education researchers: Single-sex lab team education is beneficial for female students.

Science is practiced and taught in an individualist and competitive environment, while females tend to learn better in an environment of cooperation and

connectedness to the real world. In general, solo women are less talkative than women in the majority, whereas solo men are more talkative than men in the majority (Myaskowsky, Unikel & Dew 2005). Since talking more than in a group provides more opportunities to exert influence or leadership, women are negatively affected by their solo status. Most students had the perception that girls participated more in single-gender groups than they did in mixed-gender groups. This corroborates with existing research which has concluded that boys tend to control participation in mixed-gender groups because they tend to be more dominant (Richardson, Hamrlich & Livingston 2003). Booth and Nolen (2012) examine the impact of school environment on attitudes to competition. They find that girls who are randomly assigned to all-girl groups are significantly more likely to be competitive. They also find that girls attending single-sex schools behave more competitively than girls in co-educational schools. Sullivan, Joshi, and Leonard (2010) discussed mechanisms by which sex-segregated schools might affect relative academic performance across genders. Potential mechanisms include peer effects, differential attitudes to competition, and gender differences in approaches to learning. Several studies have demonstrated that girls in single-sex schools tend to have higher levels of self-esteem than girls in coeducational schools. Kessels and Hannover (2008) showed that physics related self-concept of ability was higher for German girls in single-sex classes than girls from coeducational classes, whereas boys' self-concept of ability did not vary between the two compositions of classes. Students are more likely to enroll in optional math and science courses when they perceive themselves to possess high ability or feel confident in the subject matter. Single-sex environments might mitigate or foster some experiences that may lead girls to be motivated to pursue careers in STEM fields. Motivation is crucial to cognition and performance because motivation directs individuals' behavior. Specifically, motivation influences individuals' choices of which activities to do, level of engagement in them, and degree of persistence at them (Weiner, 1992). Past studies have recognized that the role of students' self-efficacy beliefs in a specific subject area is positively related to their academic motivation and performance outcomes in that particular domain (Pajares & Valiante, 1997).

In the laboratory, female students taking supporting roles in coed group work while male students take more leading roles. Their confidence in these areas decreases and they become less likely to follow related career paths. Arranging students in coeducational classrooms into single-gender groups would give girls the opportunity to participate equally in hands-on activities and the freedom to ask questions and offer opinions without intimidation in their group. Using single-gender

grouping is worth investigating as an option, Single-gender grouping would provide equal quality in the inquiry experience for females, where they would no longer become passive, but involved participants. Researchers and educators are at task to find methods to provide equal learning opportunities for all students, including lab equipment manipulation and data recording and processing.

In this paper, we investigate the relationships between laboratory-group gender composition and self-efficacy, lab quiz performance in a Chinese university. While our analysis provides tentative evidence that female students in single-sex groups are more likely to achieve high scores on self-efficacy and lab quiz performance than their counterparts in coed groups, we find little evidence of a similar effect for male students. Exploring the mechanisms underlying this finding is also an interesting avenue for further research. No single research on the topic has been reported before in China, it should be an important supplement to this for the international compare education.

Recommendations for Further Research

Several recommendations for further research are generated as follows:

1. It is recommended that a qualitative study should be conducted. Through unstructured interviews of some students, we can gain more insights.
2. It is recommended that lab behaviors observation should be conducted, team organization have effect upon the behavior of students.
3. It is recommended that similar studies should be executed in other university physics laboratories.

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