Influences of Gender on Computer Simulation Outcomes

Richard Lamb and Len Annetta

Abstract

Classroom environments considered to be technology rich tend to show little difference between male and female achievement outcomes in the science classroom. This study investigates the effects of internet-based chemistry simulations viewed through the lens of gender in a high school chemistry classroom. This study examines 201 students enrolled in a chemistry class nested in an urban high school setting. A pretest, post test, quasi-experimental model was used to establish the change in student achievement using gender as a predictor variable. The change in student achievement was examined using a two-way repeated measure analysis of variance (F>0.01, p<0.5). Results suggest online simulation is an effective intervention to address gender related outcomes difference in the science classroom. A continuation of this trend would suggest that technology use and science education outcomes would eventually become gender neutral.

Introduction

This study investigates the effects of internet-based simulation viewed through the lens of gender in a high school chemistry classroom. For the purposes of this study, traditional instruction is defined as rote learning, lecture, memorization, drill and practice, educator-centered learning, and teacher-led instruction. Computer / technology-aided instruction, or non-traditional instruction, is defined as learner-centered modes of education in which the learner makes use of a computer, software, or Internet websites to interact with and learn science content. For this study the use of the term male and female refers to the subject’s gender which is a social construct versus sex which is biological in nature.

Technology and Gender

A seven year study conducted by Mayer-Smith, Pedretti, & Woodrow in 1998 which included classroom observations, student interviews, questionnaires, achievement records, and journal entries, showed classrooms which are considered to be technology rich show little difference between male and females in achievement and participation within the science classroom. The results of this study were more remarkable because the classrooms used in the study did not have interventions in place to specifically address gender (Mayer-Smith, Pedretti, & Woodrow, 1998).

The Mayer-Smith study is part of a larger picture in which the previously held presumption there is “inherent biological incompatibility between femininity, science and computing” has shifted (Mayer-Smith, Pedritti & Woodrow, 2000, p. 53). Studies have shifted from this idea of an inherent incompatibility to models and questions which explore the relationship between computer experience and anxiety. Studies by several authors have shown the gender gap, and in turn anxiety about computer use, no longer exists in the same way it did, if at all (Ayersman, 1996; Barrett & Lally, 1999; Yeaman, 1992;). In fact, gender differences found via meta-analysis in 1997 were statistically significant though only very slightly (Chow, 1988; Prentice & Miller, 1992; Whitley, 1997). A continuation of this trend suggests technology use would eventually become gender neutral.

While gender does not seem to affect attitudes toward technology, the question of outcome and achievement shows some level of disagreement. A study conducted by Barrett and Lally in 1999 measuring usage levels (contributions) in an online class showed a difference between males and females. The study (n=12) reviewed the number of contributions of males and females in a distance education course. This was accomplished through review of electronic
diaries, transcripts, and questionnaires. Qualitatively, males tended to be more direct in their answers, lacking background, and simply answering questions without elaboration. Females tended to provide more background and elaboration in their answers.

The results of the Barrett and Lally (1999) study showed the mean number of contributions of males was higher than the mean contributions of the females. However, these results may need to be reconsidered since neither a level of significance nor an analysis of mean difference was completed. The low sample size (n) does not seem to allow the study to be generalized beyond this particular classroom. The Barrett and Lally study replicated a study conducted in 2001 by Myburgh, Ankiewicz, and Van Rensburg. However, the two studies did not produce similar results.

The Myburgh study of 429 South African students did not find a significant difference between the males and females in the terms of level of contribution and technology use (Myburgh et al., 2001). This result was obtained using the Attitudinal Technology Profile (ATP) questionnaire. A major criticism of the ATP is that not all of the questions seemed related to gender neutral male and female activities. Secondly, the questionnaire was only given in English and no modifications were mentioned for weaker English speakers.

Interest in Science and Science Education

There is a body of evidence within the literature suggesting there is a decline in interest among students — male and female — who desire to take part in science-related classes and careers (Smithers & Robinson, 1988). This troubling trend (the decline of interest), coupled with a general lack of scientific literacy in the population (Durant & Bauer, 1997; TIMSS 2003, 2007), results in the failure of countries such as the United States, to maintain and grow the standard of living and promote political and economic interests in the world (Dearing, 1996; Nye, 2004; Robertson, 2002). The inability to maintain a healthy and growing scientific infrastructure, an infrastructure in which science education plays a vital role, will have detrimental effects across our society.

Gender Differences in Chemistry Education

Outcome differences in chemistry education and science education, in general, do not seem to be tied to ability but to construction of gender and science by teachers and students (Kahle, Parker, Rennie, & Riley, 1993). It is thought early differences between males and females in the sciences are conserved via socio-cultural reinforcement from the surrounding society (Kelly, 1988).

The early socio-cultural reinforcement takes the form of the type of play (toys) and stereotypes each gender is shown early on. Science is often times reinforced as a male pursuit and children’s toys traditionally thought of as male in nature focus on the use of visual spatial perception. This increased exposure and training in spatial aptitude has been shown to be a predictor in chemistry outcomes (Carter, LasRussa, & Bodner, 1987). The early exposure to spatial orientation and further reinforcement due to environmental factors (e.g. teachers and social pressure) can play out as a reduction in the success of female students in the chemistry classroom and more broadly in the science classroom.

Tobin (1990) discusses the concern that in a science classroom there is a gender bias due to attention differences in the teacher student interactions. The conservation of the socio-cultural roles occurs both early through toys and play and later in life through teacher student interactions. Thus evidence has shown there is no inherent difference between males and females in the ability to process information in the science classroom. The differences may actually be due to environmentally mediated factors such as teacher attention.

Curriculum Pathways

Curriculum Pathways (CP) is a web based, online, supplemental, instructional tool based on the constructivist approach to learning (SAS, 2008). Curriculum Pathways is intended to assist classroom teachers by providing students with supplemental instruction of content via “web quest,” online simulations of chemistry phenomena at the macro and nanometer level. CP also provides for online laboratories and group interactions via focus questions, postings, and group discussion prompts.

One of the major components of the CP modules is the use of non-traditional chemistry models to aid in instruction. In these modules, students review different scalar aspects of chemistry. CP sets the conditions for conceptual change (learning) while interacting with the simulation. The student’s conceptions of how chemistry phenomena occur are challenged using online simulations, laboratories, and fact finding via web quest. By challenging student conceptions, CP causes individual students to experience disequilibrium. As a result of each student’s disequilibrium, the group as a whole experiences disequilibrium. CP then allows students to discuss and develop a social consensus to reestablish equilibrium within the individual student and group. The vague and open-ended focus question prompts students to work through this reestablishment of equilibrium. This process is equivalent to the use of problem-based learning grounded in constructivism (Annetta, Slykhuis, & Wiebe, 2007; Lamb & Annetta, 2009).
The value of curriculum pathways for both genders is seen in the treatment of the chemistry in a manner which allows for the mental visualization of the constructs. The study of chemistry is often time confounded by the difficulty or inability of the students to visualize the structure of abstract atomic models (Garnet, Tobin, & Swingler, 1995). The ability of the students to use CP to visualize complex sub-atomic models in representative or symbolic ways allows students to transfer understanding from the familiar, concrete, macroscopic level to the abstract sub-atomic level more quickly and efficiently (Barnea & Dori, 1999). This action can lead to increased understanding of the chemistry content.

**Research Questions and Hypothesis**

Computer simulations seem to produce conditions in which student understanding of conceptual information is increased more than when receiving traditional instruction alone. The research questions addressed in this study are:

1. Does gender effect student outcomes in computer mediated laboratory simulations as measured through student outcome on chemistry content related measures?
2. Does the use of technology significantly increase student understanding of measured content?

Consideration of the research questions and literature supports the following hypotheses: When gender is analyzed as a covariate with student outcomes while using computer simulations, no statistically significant difference will be found between the male and female students. Female and male online simulation groups will demonstrate a statistically significant increase over traditional instruction in their understanding of chemistry content associated with the technology-based instruction.

**Sample**

The subjects selected for this study were 201 students in eleventh and twelfth grade ranging in ages from sixteen to eighteen years old, enrolled at an urban high school in North Carolina. All subjects had completed high school Biology and Algebra I. There were 79 males and 122 females taking part in the use of technology intervention, SAS® Curriculum Pathways®. The sample is representative of the population as shown in Table 1. The male and female groups are also typical of the sample population as outlined in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>% of Population</th>
<th>% of the Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Asian</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Latino</td>
<td>10.8</td>
<td>9.1</td>
</tr>
<tr>
<td>African American</td>
<td>47.8</td>
<td>32.9</td>
</tr>
<tr>
<td>Caucasian</td>
<td>37.9</td>
<td>54.7</td>
</tr>
<tr>
<td>Multiracial</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Male</td>
<td>52</td>
<td>38.5</td>
</tr>
<tr>
<td>Female</td>
<td>48</td>
<td>61.5</td>
</tr>
<tr>
<td>Free and Reduced Lunch</td>
<td>34.4</td>
<td>18.3</td>
</tr>
<tr>
<td>English as a Second Language</td>
<td>2.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Limited English Proficiency</td>
<td>5.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 1. Demographic Makeup of the Population and Sample

**Design**

There was one instructional condition: Students taking part in the technology intervention were given the online simulation module in place of a block of instruction. Table 2 more specifically shows differences in the placement of the test, module, and instruction for each of the groups within the study.

The research design is quasi-experimental using a pretest-posttest group with non-random individual student assignment. However, classroom (class) assignment to the treatment or control group was accomplished through
random number assignment. Thus the classroom is the unit of measure for this study.

<table>
<thead>
<tr>
<th>Group n</th>
<th>Module 1 (Chemical Reactions)</th>
<th>Module 2 (Stoichiometry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Chemical Reactions</td>
<td>Stoichiometry</td>
</tr>
</tbody>
</table>

*Table 2. Experimental Design*

**Note.** Pretest (PrT), Module (M), Posttest (PT), Traditional Instruction (I), Intermediary Test (IT)

**Materials**

**Computer Simulation.** The two modules contained a computer simulation of selected laboratory topics. The modules were presented to each of the groups as part of the instructional unit for chemistry based on the National Science Standards. The modules discussed in this article are available for review at [http://www.sascurriculumpathways.com](http://www.sascurriculumpathways.com).

The first module (Chemical Reactions) presented users with a laboratory simulation of a common laboratory conducted in high school chemistry classrooms. The module also includes guiding questions to assist in the completion of the module and aid in the understanding of the content. The student is given two dropdown menus containing soluble salts. The user then selects a combination of salts and virtually "reacts" those aqueous solutions containing the salts using pictorial representations of the ions. When the user has correctly completed the reaction (balanced etc.), a video of the reaction is displayed which will show if a precipitate is formed. The students record this information in the provided tables contained in Curriculum Pathways. When all trials are complete, the student will have developed the solubility rules for double replacement reactions.

The second module (Stoichiometry) presents users with a laboratory simulation designed to review stoichiometric relationships through the use of limiting reagents. The user selects from eleven reactions. The user then interacts with each of the reactions via equations and molar ratios. While interacting with the laboratory simulation the users explore how reactant quantities affect reaction outcomes in a chemical reaction. Students completed each reaction as explained in the instructions and identify the limiting reagent. Based upon identification of the limiting reagent, the student then writes out the complete balanced equation and calculates the output of products based upon the quantity of limiting reagent on the data sheet.

**Assessments of Content Knowledge.** The students using each of the modules were given a pretest, intermediate test – after using each of the modules — and a posttest. The test questions for each group were identical, meaning the pretest, intermediary test, and posttest associated with module two for example had the same questions on each test. Each test consisted of five multiple choice questions and five free-response questions.

Validity of the tests was established through analysis of alignment to the National Science Standards for Physical Science (NS.9-12.2). Two chemistry instructors and a professor of science education reviewed the tests for clarity of the questions, appropriateness in regards to the content reviewed in the modules and taught during instruction. The experts in chemistry also ensured the alignment to the National Standards and the North Carolina Standard Course of Study.

Internal constancy was estimated using Cronbach’s alpha, the internal consistency score for each measure associated with the modules is listed in Table 3. Each of the module tests shows an adequate level of internal reliability. Module 1 shows an internal reliability of 0.78 and module 2 shows an internal reliability of 0.70.

<table>
<thead>
<tr>
<th>Test</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 (Chemical Reactions)</td>
<td>0.78</td>
</tr>
<tr>
<td>Module 2 (Stoichiometry)</td>
<td>0.70</td>
</tr>
</tbody>
</table>

*Table 3. Internal Consistency Scores for Each Test*

**Procedure**

There were five chemistry sections which were part of the study. Students participated in their assigned class sections. Each group was given the two modules as a part of a larger unit. The study took place over a six week period during the
school semester, which started in January and ended in June. The semester consisted of two nine-week quarters with each class using the block schedule. The teacher had ninety-minutes per period of instruction. Instruction in the use of the modules had been given prior to the start of the study. All groups were given access to the module after data collection to ensure equity of instruction.

Prior to the start of each unit, students in the classroom groups were given a multiple choice and free-response pretest to assess prior knowledge regarding the chemistry content being taught. The groups were then given either traditional instruction or the online simulation as instruction.

**Module 1. Chemical Equations.** The classroom groups were given traditional teacher-led instruction which consisted of one hour of lecture followed by a thirty minute demonstration of concepts associated with the lecture. Each group was then given an intermediary test to help clarify gains achieved via teacher-lead instruction prior to use of the module or additional instruction. Upon completion of the second round of instruction the classroom groups were given a posttest to assess student understanding of the content.

**Module 2. Stoichiometry.** The classroom groups were given access to the online simulation or a period of teacher instruction and asked to complete the assignment. An intermediary test was given to access student understanding of the content after use of the computer simulation. The groups were then given additional ninety-minutes of teacher-lead instruction on the topic. A posttest was administered in an attempt to measure over all differences in the student outcomes.

**Data Analysis**

Student test results were recorded by gender, module, and grouping. The scores were analyzed using two-way repeated measured analysis of variance. The mean, standard deviations, and F-statistics were calculated and recorded. Students were instructed to leave blank any questions they could not answer. Each test was out of a total of ten points, any blank answers were counted as incorrect.

<table>
<thead>
<tr>
<th>Module</th>
<th>Factor</th>
<th>Sum of Squares</th>
<th>Prob&gt;F</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 Pretest</td>
<td>Gender</td>
<td>0.291938</td>
<td>0.53610</td>
<td>No Significance</td>
</tr>
<tr>
<td>Module 1 Inter. Test</td>
<td>Gender</td>
<td>249.44979</td>
<td>0.00060</td>
<td>Significance</td>
</tr>
<tr>
<td>Module 1 Posttest</td>
<td>Gender</td>
<td>270.28873</td>
<td>0.00710</td>
<td>Significance</td>
</tr>
</tbody>
</table>

*Table 4. Analysis of Variance Comparing Module 1 (Chemical Reactions) Outcomes by Gender.*

Table 4 shows the results of the comparison of student outcomes by gender after each intervention. The F-statistic revealed no significant differences between the male and female groups taking the pretest. The low mean scores for each group shown in Figure 1 indicate both groups showed little knowledge of the concepts associated with module 1 prior to instruction. The intermediate test after the inclusion of teacher instruction shows a significant difference between the male and female groups with the females scoring lower than the males. Posttest scores for module 1 show a significant difference between the male and female scores with the females scoring +0.30 points higher on the posttest. Outcomes also show there is a significant increase in student content mastery after use of the modules.
Figure 1. Graphical comparison of module 1 (Chemical Reactions) testing outcomes by gender.

Figure 1 shows a graphical comparison of student outcomes by gender (x-axis) and test score (y-axis). Review of the graph shows females, after receiving computer instruction, showed a significant increase in content knowledge over males. Mean scores are shown as numerical values on graphic.

<table>
<thead>
<tr>
<th>Module</th>
<th>Factor</th>
<th>Sum of Squares</th>
<th>Prob&gt;F</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 2 Pretest</td>
<td>Gender</td>
<td>1.37554</td>
<td>0.4472</td>
<td>No Significance</td>
</tr>
<tr>
<td>Module 2 Inter. Test</td>
<td>Gender</td>
<td>427.06767</td>
<td>0.6908</td>
<td>No Significance</td>
</tr>
<tr>
<td>Module 2 Posttest</td>
<td>Gender</td>
<td>42.48078</td>
<td>0.0003</td>
<td>Significance</td>
</tr>
</tbody>
</table>

Table 5. Analysis of Variance Comparing Module 2 (Stoichiometry) Outcomes by Gender

Table 5 shows the results of the comparison of student outcomes by gender after each level of intervention. The F-statistic revealed no significant differences between male and female groups for the pretest and intermediate test. The low pretest mean scores for each group indicate both groups showed little knowledge of the concepts associated with module 2 prior to instruction. The posttest shows a significant difference between the male and female groups with females scoring higher than males.
Figure 2. Graphical comparison of module 2 (Stoichiometry) testing outcomes by gender.

Figure 2 shows a graphical comparison of student outcomes by gender (x-axis) and test score (y-axis). Review of the graph shows females, after receiving computer instruction, showed a significant difference and increase in content knowledge when compared to males. Mean scores are represented by the numerical values found on the graphic.

Discussion

The primary purpose of this study was to compare outcomes of computer mediated instruction as a function of gender. It was hypothesized when gender is analyzed as a covariate of student’s outcomes incorporating the use of computer simulations, no statistically significant difference would be found between the male and female students. Rejection of the hypothesis would result from statistically significant differences in the intermediary and posttests directly after the module was used by the students. This result is precisely what is found in the results. The lack of a significant difference in the pretest scores for all modules shows no one group of students showed more prior knowledge than another relating to the measured chemistry content. All students worked from the same level of prior knowledge concerning each topic covered by the modules. This indicated that any achievement gains shown were a result of instruction or module use. In addition the rejection of the hypothesis supports suggestions in the literature that the use of computers is an equalizing factor helping to remove gender bias within science education.

Traditional instruction results in module 2 suggest that the traditional instruction may result in a pro-male achievement environment. This supports outcomes in the Barrett and Lally study which shows that the average number of contributions of male students tends to be higher. The larger number of contributions by male students may result in less attention given to the females of the classroom by the teacher. This may be particularly true unless specific interventions are in place to account for attention differences. This lack of attention from the teacher may translate to lower achievement on content measures.

Computer instruction does not result in significant outcome differences as a function of gender. This is possibly due to the “one-on-one nature” of computer aided instruction. The “one-on-one” nature allows for equal “attention” and feedback— from the computer— to be given to each student when constructing knowledge. This is evidenced in module 2 by the lack of significance in difference in intermediate test scores after module instruction. Further, the mean scores are almost identical with only a +0.3% difference between the female and male means. Contrasted with module one, male scores after traditional instruction show a +1.4% difference in performance over females. This indicates there may be a male bias in the classroom which may affect female outcomes. These results answer research question 1 and show the use of technology can be effective in mitigating gender bias in the classroom.

Results also suggest the use of computer aided instruction does show an increase in content knowledge when compared to traditional instruction. This is indicated by a comparison of the results of modules 1 and 2 across genders.
All simulation users show an average increase of +26% in outcomes when compared to traditional instruction which shows a +13.5% increase in student outcomes. These results answer research question 2 and show the use of computer aided instruction does result in an increase in student learning.

Conclusion

This study provided evidence that the use of online simulations is an effective intervention for addressing gender bias in the science classroom. With the relatively low number of females entering the sciences (physical sciences) due to lack of interest, an increase in success in the science classroom may allow for an increase in the movement of females into the science field. Technology can act as the bridging mechanism for that action and policies promoting the use of technology as a means to interest not just females but all students in the sciences. Future areas of study may address specific qualitative factors which cause gender effect outcomes associated with technology use.

References


Authors

Richard Lamb is a graduate student in science education at North Carolina State University. His research interests have revolved around the measurement of student outcomes in science, mediated through various technologically based instructional strategies. Working with Len Annetta he has focused on assisting his research into synchronous interactions in virtual environments through statistical support and instrument development. Upon completion of his degree he would like to continue the development of his research into technology mediated science education and move into a professorship at a research institution.

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