Gender Equitable Curricula in High School Science and Engineering

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Abstract
As part of a Research Experiences for Teachers (RET) supplement to the VaNTH Engineering Research Center for Bioengineering Educational Technologies (www.vanth.org), an interdisciplinary group of secondary teachers and college faculty have come together to develop and field test new materials for secondary school science classrooms. The instructional units have as their starting point a “grand challenge” that not only assists the students using the materials to see a real world application of the science knowledge they will be learning but also serves as a focus for student understanding. For example, the grand challenge for the Optics Mosaic centers on the need for the student to select and justify a remedy to their mother's need to get rid of her glasses. Students study the fundamentals of optics within the context of solving this grand challenge.

Research has shown that young women learn science better when certain characteristics of the classroom and curriculum are met. Specifically, girls learn science better when the curriculum specifically links mathematics, science, and technology to the real world and integrates these topics as well. Girls learn well when the coursework is collaborative and utilizes girls’ verbal skills. Literature has also shown that girls learn science well in classrooms that use hands-on investigations while encouraging girls to be experts and technology controllers. These characteristics help girls to have a feeling of self-efficacy necessary to combat negative attitudes and personal disbeliefs. Girls’ interest in physics can be stimulated by relating content to prior experiences, encouraging discussion on the social importance of physics, and showing physics in relation to the human body. While acting as facilitators to higher cognitive functions, educators should encourage girls to concentrate on how the right answer is determined and not just what the right answer is.

Through ANCOVA analyses of pre- and post-tests in control and experimental classrooms, previous studies have established that the students in the experimental classrooms better learn the basic science in the instructional units previously mentioned than the control students. In most cases, the students in the experimental classrooms perform better on 'near-transfer' questions than their control classroom counterparts as well. Additional ANCOVA analyses on three of the curriculum mosaics, Hemodynamics (fluid dynamics of the circulatory system), Optics (LASIK and optics), and the Electrocardiogram (cardiac anatomy and physiology), were performed on the
2003-2004 school year data in regard to gender differences. In many cases, the females lagged the males in the control group and exceeded the males in the experimental group. In a few cases, the females closed the gap on the males from the control to experimental group. While the gender by group interaction effect was not statistically significant for any of the units, these data indicate that the treatment seemed to meet the needs of the females.

**Introduction**

The VaNTH Engineering Research Center for Bioengineering Educational Technologies is funded by the National Science Foundation (NSF EEC 9876363) as one of the several engineering research centers. While its focus is primarily at the undergraduate and graduate level of college education, a significant outreach program to the high school level exists. As part of a NSF Research Experiences for Teachers (RET) supplement, an interdisciplinary group of secondary teachers and college faculty have come together to develop and field test new materials for secondary school science classrooms.

The design utilized in the curriculum modules makes use of a strong contextually based “Challenge” followed by a sequence of instruction where students would attempt to “Generate Ideas” (first thoughts on the challenge), view “Multiple Perspectives” of others commenting on the challenge and possible ways to address it, participate in extended “Research and Revise” activities where data and information would be gathered to help the student address the challenge, followed by “Test your Mettle” a formative self-assessment and “Going Public” where students solutions would be made public to peers and others. While having been implemented in a limited number of K-12 studies, results were positive for students working with this design, referred to as the “Legacy Cycle”, by the developers.

Research has shown that young women learn science better when certain characteristics of the classroom and curriculum are met. Specifically, girls learn science better when the curriculum specifically links mathematics, science, and technology to the real world and integrates these topics as well. Girls learn well when the coursework is collaborative and utilizes girls’ verbal skills. Literature has also shown that girls learn science well in classrooms that use hands-on investigations while encouraging girls to be experts and technology controllers. These characteristics help girls to have a feeling of self-efficacy necessary to combat negative attitudes and personal disbeliefs. Girls’ interest in physics can be stimulated by relating content to prior experiences, encouraging discussion on the social importance of physics, and showing physics in relation to the human body. While acting as facilitators to higher cognitive functions, educators should encourage girls to concentrate on how the right answer is determined and not just what the right answer is.

**Module Overview**

Through ANCOVA analyses of pre- and post-tests in control and experimental classrooms, previous studies have established that the students in the experimental classrooms better learn the basic science in the instructional units previously mentioned than the control students. In most cases, the students in the experimental classrooms perform better on 'near-transfer' questions than their control classroom counterparts as well. Near-transfer questions are questions in which the same basic science principals are applied to a new application that was not used in the course of study. In this study, additional analysis was done on the data from the

Accompanied by the figure to the right, the electrocardiogram mosaic began with the following grand challenge question, “Suppose one of your teachers visits his doctor and, as a part of a routine exam, he has his electrocardiogram (ECG) measured. The results are shown below. Should your teacher be concerned about these results?” After initial brainstorming by the students, the mosaic was broken down into three legacy cycle modules. Challenge 1 focused on how the heart beats and why. Challenge 2 focused on what the normal ECG measures and what information is reflected on the normal ECG. Challenge 3 focused on how the ECG reflects abnormalities of rhythm and structure. Major topics of the typical Physics curriculum taught in this mosaic included electric fields, dipoles, and vector projections. Major topics of the typical Anatomy & Physiology courses that are included in this mosaic are the following: cardiac cycle, cardiac anatomy, the heart’s intrinsic conduction system, the cardiac action potential, and basics of the electrocardiogram. This mosaic was designed for use in Physics and Anatomy & Physiology classrooms.

The grand challenge for the Optics mosaic is “Your baby brother has broken your mom’s glasses (for far-sightedness) for the umpteenth time. She is fed up and would like to consider what she can do so that she never has to deal with them ever again. (She cannot wear contacts!). She looks to her smart kid – you – to help her. So what is her best option? How does it work? Is it safe?” Individual challenges for the mosaic focus on how vision takes place, the changes that occur to the eye in nearsightedness or farsightedness, and what are the options when one considers corrective eye surgery. The materials allow students to develop their own understanding of several optics concepts such as Snell’s Law, lenses, refraction, etc. as well as biology related concepts of eye anatomy, vision, etc. A variety of instructional activities are part of the mosaic including lens laboratories, historical information on eyeglasses and how they are currently prescribed, and the LASIK process itself. This mosaic was designed for use in Physics and Anatomy & Physiology classrooms.

The Hemodynamics mosaic has as its grand challenge “You, as a medical student, are presented with a patient with a heart murmur that can be heard throughout diastole. Listen to the audio file that accompanies this module to hear the murmur through a stethoscope. Pressure measurements made in the heart are shown below. Valve disease is suspected. Which valve and what condition are most likely to be causing this heart sound? Why?” Challenge 1 focuses on the circulatory system as a whole. The second challenge investigates principles of fluid dynamics that are relevant in a study of the body’s circulatory system. The third challenge links these topics together by asking about pressure versus time patterns expected in the major valvular disorders and what is responsible for murmurs. From the traditional Anatomy and Physiology curriculum,
students learn about the cardiac cycle as a whole as well as circulatory system anatomy. Students compare and contrast arteries and veins macroscopically and microscopically. From the Physics curriculum, students learn fluid mechanics including pressure, force, Bernoulli’s equation, etc. Assessments included developing an infomercial or brochure to teach a peer about the circulatory system as well as informational brochure about hypertension. After listening to audio files on the heart sounds and various murmurs, students perform auscultation on themselves and take a partner’s blood pressure. Additionally, students analyze cardiac pressure tracings of various valvular diseases and ultimately answer the grand challenge question. This mosaic was designed for use in Physics and Anatomy & Physiology classrooms.

**Study Details**

This small study was implemented using several classrooms. For the Hemodynamics Mosaic, one Biomedical Physics class at a private school (N=17, 7 female) named "experimental" and one AP Physics B class at a comprehensive public school (N=11, 8 female) named "control" were used. For the LASIK/Optics Mosaic, the same Biomedical Physics class was used as the experimental group and a small Physics 2 class (N=6, 1 female) was used at the same school as a control. Finally for the Electrocardiogram Mosaic, the Biomedical Physics class was used yet again as part of the experimental group. Additionally, an Anatomy and Physiology classroom at a rural public school (N=15, 11 female) and another Anatomy and Physiology classroom at a suburban public school (N=16, 10 female) were a part of the experimental group. For the control group, a control classroom was used at each high school with a total of 43 students, 29 female. In each case, the control classroom was chosen as a curricular match for the topics being tested and other demographics such as gender and race were as closely matched as possible in this small study. All teachers are very experienced teachers in their fields.

The pre-test items were measures of knowledge of the underlying concepts of the domain covered by the instructional units. The pre-test items included multiple choice, short answer, or relatively simple computational problems and varied from 7 to 12 separate questions. On the post-test, items that had appeared on the pre-test were repeated first. It was expected that both experimental and control students would do rather well on this section of the post-test since the basic concepts that were tested were those that would have normally been taught in a Physics or Anatomy and Physiology course. Secondly, a set of application type items were prepared that required the student to use basic concepts to solve a problem or answer a more complex question than was found on the first section of the post-test. These items were designed to resemble traditional, yet challenging, chapter test types of questions. The final section was a set of questions that were very specific to the module that the experimental students used, e.g., module specific. It was expected that students in the control group would generally not do very well on this type of question, due to its specific nature but it did allow some measure of how well the students in the experimental group had developed their thinking in regard to the module/mosaic that was developed. Control group students who were good at transferring knowledge would be
expected to meet with some success on these questions however. These module specific problems were usually multiple step numeric or explanation questions that were meant to be somewhat difficult even for the students who had studied the unit.

In each of the three curriculum modules, teachers in the experimental classrooms gave the pre-test and post-test immediately before and after the use of the new materials. In the control classrooms, teachers gave the instruments before and after their curriculum unit on the relevant physics or anatomy and physiology topic (for instance, before and after the unit on fluid dynamics for the hemodynamics control). All students were given as much time as they needed to complete the materials and were not allowed to use any references.

**Results**

The ANCOVA analysis method was selected to analyze the results of this study. Because students at the two schools may not have started with the same baseline of knowledge, the pre-test must be used as a covariate, a variable that represents a source of variation which has not been controlled for in the experiment and is believed to affect the experiment’s outcome. The fixed factors were the group, experimental or control, in which each student belonged and each student's gender. ANCOVA adjusts the dependent variable so as to remove the influence of the pre-test on the post-test. ANCOVA also allows one to assess the statistical significance of any interactions between the factors, gender and group in this case. Prior ANCOVA analysis has already shown that the curriculum modules are more effective than traditional curriculum in teaching the basic science. The purpose of this study was to look across several modules to see if gender differences exist. To make this assessment, this study will look at the group interaction of study group and gender.

The results of each of the three sections of the tests (pre-test questions repeated, application items, and transfer items) are shown in Figures 1, 2, and 3 below and are broken down by both gender and group. The reported estimated marginal mean values have been adjusted for the covariate pre-test. The statistical results are summarized in Table 1.
Figure 1. Hemodynamics Mosaic Test Results. The first cluster of bars represents the results of the pre-test questions that were repeated on the post-test (maximum possible points = 7). The middle cluster represents the post-test application items (maximum possible points = 25). The last cluster represent the near-transfer post-test items (maximum possible points = 10).

![Hemodynamics Mosaic](image)

Figure 2. Electrocardiogram Mosaic Test Results. The first cluster of bars represents the results of the pre-test questions that were repeated on the post-test (maximum possible points = 9). The middle cluster represents the post-test application items (maximum possible points = 21). The last cluster represent the near-transfer post-test items (maximum possible points = 10).

![Electrocardiogram Mosaic](image)
Figure 3. LASIK/Optics Mosaic Test Results. The first cluster of bars represents the results of the pre-test questions that were repeated on the post-test (maximum possible points = 12). The middle cluster represents the post-test application items (maximum possible points = 14). The last cluster represent the near-transfer post-test items (maximum possible points = 6).

Table 1. Statistical results: Statistical significance of group*gender interaction in the ANCOVA analysis.

<table>
<thead>
<tr>
<th></th>
<th>Hemodynamics</th>
<th>Electrocardiogram</th>
<th>LASIK/Optics</th>
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<td>Pre-test Items</td>
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<td>Application Items</td>
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<td>Transfer Items</td>
<td>0.258</td>
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</table>

**Interpretation**

In many cases, the females lagged the males in the control group and exceeded the males in the experimental group. This pattern can be seen in the important application items of the Hemodynamics and LASIK/Optics mosaics and in the transfer items in the Hemodynamics mosaic. In a few cases, the females closed the gap on the males from the control to experimental group. While the gender by group interaction effect was not statistically significant for any of the units, these data indicate that the treatment seemed to meet the needs of the females but do not appear to provide special support for females as compared to the control group. The materials are effective for both genders. These results have ramifications for the design of future high school science curriculum and should be considered carefully.

Additional field test studies are underway in the 2004-2005 school year to include additional curriculum modules developed under the same project and to include additional subjects in these same mosaics. Also, student attitude towards science and school in general will be assessed to see if students better enjoy and value science after using these curriculum modules.
References

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