Using a Study of Skin to Teach Stress and Strain in High School Physics, Anatomy & Physiology, and Engineering

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***Abstract* - A new high school curriculum unit makes use of a study of skin's elasticity to teach the topics of stress and strain and skin anatomy and physiology. This curriculum has been designed by the NSF-funded VaNTH Engineering Research Center at Vanderbilt University. The module begins with an engaging challenge question and uses a highly interactive, lab-based curriculum based on the Legacy Cycle. The challenge question involves an elderly patient who has an apparent skin tear. Experimental and control students completed a short pre-test intended to measure basic understanding and a post-test composed of three parts: the pre-test repeated, more complex questions similar to a traditional test, and near-transfer questions. Two sets of tests were written: one for physics and one for biology. The experimental group significantly outperformed the control group on both the biology and physics tests (p<0.02) as measured by ANCOVA. These results indicate that this biomedical engineering curriculum appears to have a positive effect on students' ability to master and apply skin elasticity.**

Index Terms – physics, physiology, pre-college, VaNTH

INTRODUCTION

The Vanderbilt-Northwestern-Harvard-MIT Engineering Research Center for Bioengineering Educational Technologies (VaNTH ERC) 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 university education, a significant outreach program to the high school level exists. This outreach program has involved the development of numerous curriculum modules for use in high school science classes [1-3]. Much of the work done in VaNTH has been based upon the text, *How People Learn* (HPL) [4].

HPL learning theory incorporates four "centerednesses" that work synergistically to optimize learning. When these four are in place, studies show that students increase both their content knowledge and their ability to apply that knowledge in new situations – i.e., their *adaptive expertise* [1-2,5-7]. First, the learning environment must be *knowledge-centered* -- appropriate information should be presented in an appropriately sequenced and organized way. Second, the environment must be *student-centered* -- lessons should seek out students' prior conceptions and misconceptions, help students make connections with prior knowledge, and be relevant to students' own lives. Third, the learning environment must be *assessment-centered* -- it should include opportunities for formative feedback for both students and instructors: students benefit from opportunities to check their own understanding and instructors from opportunities to assess the effectiveness of their teaching. Finally, a learning environment must be *community-centered* -- students should be provided opportunities to learn collaboratively.

According to HPL theory, students learn best when (1) presented with organized information that (2) relates in some way to their own experiences, and they are given the opportunity to (3) test themselves on their own understanding and to (4) work to develop their understanding with other students. Legacy cycle incorporates these four influences on learning by providing a rich, contextually based problem, relevant in some way to students' lives, and allowing students to engage deeply with that problem in ways that include opportunities for collaboration with other students and for self-assessment.

The design utilized in the curriculum modules that incorporates HPL theory [8] 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), and view "Multiple Perspectives" of others commenting on the challenge and possible ways to address it. Students then 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, but growing, number of K-12 studies [1-3] results were positive for students working with this design, referred to as the "Legacy Cycle", by the developers.

MODULE DETAILS

The Skin Elasticity unit has as its challenge, "You are a doctor and you get a phone call at your office from an elderly patient. She tells you that she fell down and has a large wound on her arm above the elbow that appears to be a skin tear. You tell her to come into the office so that she can have it examined, but in the mean time suggest she finds a bandage to protect the wound until she gets there. What do you suggest she use to close the wound? What properties of a bandage will be required to close the wound?"

From the traditional Anatomy and Physiology curriculum, students learn about the components and function of skin. From the Physics curriculum, students learn about elastic deformation, Young's modulus, shear modulus, and Hooke's Law. Students complete a homework assignment utilizing the equations of stress and strain as well as Hooke's Law. Students are then given the task to create, implement, and report on an experiment designed to answer the following problem that relates to the challenge question: *What type of temporary wound care would best mimic natural skin?* They are provided with materials including a ring stand, clamps, and weights. Chicken skin is provided as an alternative to human skin and an assortment of bandages is made available. Students must create their own hypothesis and experimental procedure. After these are approved by the teacher, students must collect their own data, analyze it, and create a scientific poster explaining the results of their work.

This curriculum unit was designed for and used in Physics and Anatomy & Physiology classrooms. In 1996, the National Academy Press published the National Science Education Standards that provide guidance for the instruction of all science students in the USA. The standards were written to embody equity and excellence and to provide a vision for a scientifically literate populace. This curriculum unit addresses the National Science Education Standards' Content Standard A that focuses on the student developing the abilities necessary to do scientific inquiry and understandings about inquiry. Content standards B, E, and G, are addressed through the module as students learn more about matter and organization in living systems; technological design; personal and community health; and science as a human endeavor. Teaching standards A, B, C, D, and E are met as are Assessment standards A, C, and D. The Teaching standards ensure an inquiry based, appropriately paced science program in which teachers guide and facilitate learning while maintaining an ongoing assessment of their teaching and student learning. The Assessment standards ensure that the assessments used are fair and authentic and that they give information to the teacher about whether or not the student has met the desired learning goals. The American Association for the Advancement of Science's Project 2061 Standards are addressed also [10]. In particular, the benchmarks for Physics Health, the Designed World, Habits of Mind, the Human Organism, and the Physical Setting are met.

STUDY DETAILS

This small study was implemented using eight total classrooms. For the experimental groups one Biomedical Physics class at a private school (N=9; 4 female) was used in both the biology and physics data sets; one Physics class at a public school (N=6; 1 female) was used; and two Physics classes at a private school were used (N=23, 9 female). For the control groups two Anatomy and Physiology classes at a parochial school (N=29, 21 female) and four Physics classes at a private school were used (N=66, 23 female). All of the classes used curriculum content at approximately the same level.

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 six multiple choice questions about basic vocabulary and relationships. 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 science 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 to avoid having students top out on the test, chapter test types of questions. Topics on the physics test included problems on Young's modulus, shear modulus, and Hooke's Law. Topics on the biology test included many more details about the skin's structure. The final section was a set of questions that were more specific to the module that the experimental students used. 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 included explaining stretch marks on pregnant woman and explaining an experimental technique for determining how much a pregnant mother's belly could stretch without creating stretch marks.

In the experimental classroom, the pre-test and post-test were given immediately before and after respectively the use of the new skin elasticity curriculum under study. In the control classrooms, the pre-test and post-test were given immediately before and after respectively the use of traditional curriculum. In both classrooms, students were required to work individually and without the help of notes or the teacher.

TABLE I
SKIN ELASTICITY BIOLOGY TEST RESULTS

	Experimental Mean	Control Mean	Max Points Possible	P-value
Pre-test Items	4.55±0.39	3.41±0.22	6	0.015
Application Items	3.34±0.33	2.17±0.18	5	0.004
Transfer Items	3.61±0.28	0.09±0.15	7	<0.001

TABLE II
SKIN ELASTICITY PHYSICS TEST RESULTS

	Experimental Mean	Control Mean	Max Points Possible	P-value
Pre-test Items	4.24±0.14	4.50±0.11	6	NS
Application Items	10.19±0.58	6.67±0.44	23	<0.001
Transfer Items	4.41±0.21	0.76±0.16	7	<0.001

RESULTS

The ANCOVA analysis method was selected to analyze the test results of this study [11]. 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 factor was the group, experimental or control, in which each student belonged. ANCOVA adjusts the dependent variable so as to remove the influence of the pre-test on the post-test. The ANCOVA analysis will allow the null hypothesis that the treatment effects are not different when applied to individuals with the same baseline test score. In other words, if we were to start with identical students in each group would the skin elasticity curriculum better teach the principals of skin elasticity than traditional curriculum?

The results of each of the three sections of the tests (pre-test items repeated, application items, and transfer items) are shown in Table I below for the biology comparison. The results of the three sections of the tests for the physics comparison are shown in Table II. The p-value shown reflects the results of the ANCOVA analysis completed on that section of the post-test using the pre-test as a covariate.

INTERPRETATION

These results indicate that this BME curriculum appears to have a positive effect on students' ability to master and apply skin elasticity. Students in the experimental group performed significantly better than control students on tests of basic vocabulary and concepts as well as on traditional test-type problems of the basic physics or skin anatomy and physiology. Students in the experimental group were also better able to apply their new knowledge to near transfer problems, though one might expect that given the nature of the transfer questions. In these types of studies the claim that the application and particularly the transfer items are too different from the experiences that the control group might have in their regular classes is a concern. Even considering this possibility, the differences between the groups on the pre-test items is sufficient to indicate a difference in instructional design was a significant factor.

Studies such as this and others in the literature indicate that both challenge-based curriculum and curriculum based in an applied topic such as biomedical engineering may significantly improve students' mastery of the basic science. Through the use of the challenge question, students are better to able why they are studying basic science as they are forced to apply it immediately to some real world problem. Materials based in engineering also allow secondary students the opportunity to be exposed to engineering as a possible field of study and employment. These suggestions have ramifications for the design of future high school science curriculum and should be considered carefully.

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