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Haptic Abilities and Their Impact on Teaching and Learning in the STEM Fields

Dr. Nancy E. Study, Pennsylvania State University, Erie
Mr. Robert Edwards, Pennsylvania State University, Erie

Bob Edwards has a BS in mechanical engineering from Rochester Institure of Technology and a MS in mechanical engineering from Gannon University. He is currently a Lecturer of Engineering at Penn State Erie, The Behrend College. He teaches in the Mechanical Engineering Technology department. His primary teaching interests are in the fluid and thermal sciences, and teaches Thermodynamics and Heat Transfer. Additionally, he teaches a variety of other courses including Basic Electricity for MET, Statics and Dynamics.

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Introduction

Haptic ability refers to an individual's sensitivity to touch and the ability to combine partial tactile information about an object into a whole mental image. The ability to create mental images, to visualize, is linked with success in engineering and technology fields of study. Coursework including sketching and the use of manipulatives, along with other haptic or hands-on activities, has been shown to increase the spatial skills of university level engineering and technology students who scored below the expected mean on the Purdue Spatial Visualization Test (PSVT) [1]. Previous research also indicates that students entering into the STEM fields tend to have higher haptic abilities than the population as a whole. In one of those studies, a sample of over 200 freshman engineering students was found to have haptic abilities at one standard deviation above the mean expected for neurotypical adults over the age of 18 [2].

Even though research indicates the presence of above average haptic abilities for those self-selecting into the engineering and technology fields, and a preference for learning from hands-on activities, students are beginning their university studies with little to no practical experience in design or manufacturing processes. Much of the technical experience they do have is from completing virtual labs and other computer-based instruction in high school which does not always translate into useful abilities in a university laboratory environment with physical equipment. These virtual activities do not provide realistic practical experience and they do little to improve spatial skills. Students beginning their engineering and technology studies with poor spatial skills have lower levels of academic success at university. The use of haptic activities has been shown as a necessary component in improving spatial skills, not only for engineering students but across curricula. A 2005 paper by Sorby, Hungwe, and Charlesworth[3] noted that non-engineering students who received instruction intended to improve spatial abilities, subjects who only used software for training had significantly lower gains in PSVT scores than did subjects who completed workbook activities that required sketching and the use of manipulatives (snap cubes) to build objects.

The process of testing pre-service teachers and the dissemination of information about the importance of haptics could have a positive impact on the way they teach and present information when the get in the classroom and thus prepare students better for work and study in the STEM fields. The use of simple haptic or hands-on activities in precollege STEM courses should be encouraged to take advantage of students' natural abilities and to help improve their spatial skills which could enhance their chances of success in future academic and career pursuits.

Haptics and Visualization in STEM Education

While there are certain benefits to using virtual instruction in engineering and technology, including potentially lower cost and little/no equipment maintenance, 3D interaction using software is often simplified and does not always accurately reflect actual function which in turn does not yield optimal results. These results are seen not only in inadequate precollege preparation in engineering and technology, especially in the spatial skills necessary for success in engineering design and engineering graphics courses, but even in performance in required mathematics and physics courses. According to Sourin and Wei [4], the use pictures or symbols of 3D objects on screen can lead to weakened mathematical competencies when dealing concrete 3D models, analysis of solid figures, and vector analysis. The use of haptic activities has also been found to enhance abstract phenomena when teaching physics [5].

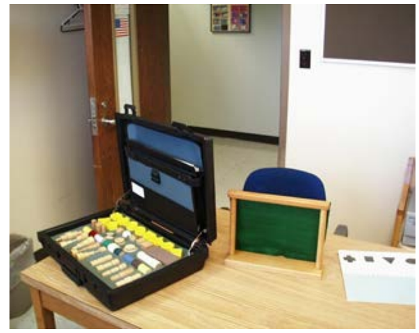
Much of the research done involving using haptic activities in the classroom involves the use of computer-based equipment such as force feedback devices. In the case of many engineering and technology courses, especially those in engineering graphics and engineering design however, a variety of low tech activities may be implemented that take advantage of the haptic tendencies of the students and improve their spatial skills, which in turn can lead to higher levels of retention. Activities as simple as sketching and using manipulatives can have a significant impact on student success. Improving visualization abilities by implementing haptic activities as part of instruction in an introductory engineering graphics course improved overall GPAs and GPAs in STEM courses, and also increased retention in the major and retention at university in a sample of minority engineering and technology students [6].

The Haptic Visual Discrimination Test

The Haptic Visual Discrimination Test (HVDT) is a standardized and quantitative test that measures skills in tactile sensitivity, spatial synthesis and the ability to integrate partial information about an object into a whole and has developmental norms derived from a sample of over 2,000 “normal,” not physically or mentally impaired, individuals aged three years to adult.

Pre-, post-testing, and split-half reliability procedures determined the reliability of the test. Test-retest reliability was between .91 and .93 with coefficients of determination between .83 and .87 indicating that between 83 and 87 % of the variance could be accounted for by haptic-visual discrimination skills. The split-half reliability tested with the Spearman-Brown formula was .90 to .91 [7].

The HVDT is administered individually with the subject sitting across from the examiner at a desk or table. An identification chart and a visual screen are placed in front of the subject. The case containing the test objects is in a position where the subject cannot view the objects in the case. The subject places their right hand through the opening in the visual screen and the examiner places an object in their hand. The subject manipulates the object in their right hand without seeing it, and then is asked to point to the corresponding object on the identification chart with their left hand.



A picture showing the typical setup of the testing environment from the test examiner’s perspective is shown at the right. There is no set time limit to administer the HVDT and the average time required by subjects is 10 to 15 minutes. Scores are recorded on a standard score sheet by the examiner.

Proposed Study

The authors of this paper are proposing a study to determine if college students preparing to become teachers in the STEM fields have similar haptic abilities as the students they will be teaching and to educate these pre-service teachers in the importance of using haptic activities and their relationship to the development of spatial skills. The importance of spatial skills to student success in the STEM fields, especially engineering and engineering technology, will also be addressed. The study will be conducted in three phases.

The goal of phase 1 is to gather additional data on freshman engineering and engineering technology students to verify previous research results indicating above average haptic abilities based on HVDT scores. Currently two sets of HVDT testing materials have been obtained, along with IRB approval to test freshman engineering and technology students over the course of five years. Testing will begin in the spring 2014 semester on students enrolled in introductory engineering graphics courses. These subjects are primarily freshmen majoring in mechanical or plastics engineering technology, or integrated business and engineering. Students in the course are administered the PSVT as a pretest and posttest as part of regular classroom activities and the mean scores for these students are similar to the expected mean for freshman engineers based on previous research. Course content includes multiview projection, dimensioning, working drawings, creation of design solution alternatives, and CAD. Instruction techniques include sketching and the use of manipulatives along with lecture, demo, and CAD tutorials.

In phase 2, the assessment of haptic tendencies of college students who plan to become elementary or secondary STEM teachers will be undertaken. Recruitment of subjects will begin later in 2014. The primary reason for this testing is to determine if the haptic tendencies of these future teachers are similar to students self-selecting into engineering related majors. Subjects participating in this phase of the study will be instructed in the importance of visualization to success in STEM fields, especially engineering, and the role that haptic activities play in improving spatial skills. It is essential to disseminate an understanding of haptic abilities and that effective instructional activities need not involve expensive technology to positively impact students.

During phase 3 we will conduct a detailed analysis of the test results to determine if there is any difference among three groups – the overall population of neurotypical adults (data already exists), freshman engineering students, and future STEM teachers. The culmination of these three phases will help determine the focus of future research in this area including outreach to increase knowledge of the importance of haptic activities in STEM instruction.

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