

VaNTH-An Engineering Research Center Aimed at Bioengineering Education

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Abstract - The Vanderbilt-Northwestern-Texas-Harvard/MIT Engineering Research Center for Bioengineering Educational Technologies (VaNTH) is an ERC aimed at developing a new approach to bioengineering education. The goal of the VaNTH ERC is to integrate learning science, learning technology, assessment and the domain subjects of bioengineering into a new paradigm for the education of bioengineers. VaNTH has formulated concepts from learning science into a fundamental hypothesis--the "How People Learn Framework" (HPL). Achievements of the center include the following: 1. the identification of principles based on HPL that allow the design of effective instructional modules; 2. the development of principles for the evaluation of effectiveness of VaNTH instructional systems; 3. testing of new materials has occurred in 55 courses with a student population of 2,123 students with diverse backgrounds; 4. new technologies for interactive presentation of bioengineering to students, and for designing, assembling and delivering a range of technology-based instructional materials.

Index Terms – ERC, adaptive expertise, bioengineering education

INNOVATION IN ENGINEERING

Recently, there has been a significant concern expressed by academic, scientific, business and governmental leaders regarding the ability of the United States to compete in a global market [1,2,3]. A persistent theme in these discussions is the role and importance of scientific and engineering education in making the US workforce competitive. Issues regarding "innovation" are prominent in these discussions, as well as other important characteristics. A key question is: *How can these concepts be effectively designed into the engineering education system?* Learning scientists have conceptualized many of these ideas as "adaptive expertise."

Clough et al.[2] emphasize that the "Engineer of 2020" should be characterized by strong analytical skills, practical ingenuity, creativity, high ethical standards, dynamism, agility, resilience, flexibility and abilities for lifelong learning

ADAPTIVE EXPERTISE

Adaptive expertise is a desirable goal for learners in any field. Adaptive experts have deep content knowledge in their fields that is contextualized and automatized for efficient access in use [1,4,5]. They are appropriately flexible and consider multiple solutions to problems [6]. They seek opportunities for new learning throughout their careers [7]. They monitor their own state of knowledge [8]. Adaptive expertise is often contrasted to routine expertise. Routine experts have the content knowledge of adaptive experts, but lack other key characteristics⁷. Particularly, they tend to perform less flexibly in novel situations. Developing adaptive expertise is critical in fields like engineering in which the knowledge changes quickly [9].

We are interested in how people move toward adaptive expertise, even in contexts like undergraduate education in which they are unlikely to reach full levels of adaptive expertise. We have used a developmental model for adaptive expertise from Schwartz, Bransford, and Sears[10]. This model includes axes for growth along two dimensions: innovation and efficiency. Innovation is the adaptive aspect. It addresses how people react in new situations.

Efficiency is using the knowledge a person has effectively, quickly and appropriately. We suggest that if people experience consequential opportunities to engage in activities that promote both efficiency and innovation, they can progress along an adaptive expertise trajectory. Curricula based on How People Learn (HPL) principles include experiences that improve students' efficiency and innovation[12,13].

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HPL FRAMEWORK

The “How People Learn” (HPL) [11, 14, 15] framework is based on principles for the design of effective learning environments stemming from educational research. An HPL learning environment is student centered, knowledge centered, assessment centered, and community centered. A student-centered learning environment uses students’ current capabilities as a starting point for learning. A knowledge-centered learning environment focuses teaching on the important content in the domain and on achieving mastery in the content area. An assessment-centered learning environment builds in opportunities for students and teachers to acquire feedback on students’ progress throughout the learning process and thus monitor and adjust where knowledge and skills deficiencies exist. A community-centered learning environment is appropriate to the community context and builds a community that promotes learning. In addition to improving the learning of factual material, these curricula led bioengineering students to outperform on adaptive expertise measures compared to students learning in traditional lecture format [12,13].

To integrate various types of instruction for engineering, VaNTH implemented the HPL framework with the technology of the STAR.Legacy (SL) Cycle (Schwartz et al [16]). Case-based learning can be beneficial in practical fields that require the mastery of significant amounts of factual information, such as law and medicine (Williams[17]). For this reason, challenge cases are the motivating or anchoring activity in the SL Cycle. Another finding is that students learn more when they generate ideas and attempt to solve problems prior to consulting resources and hearing expert opinions (Schwartz & Bransford [18], Schwartz & Martin[19]). The SL Cycle gives students the opportunity to generate their own ideas and solutions before they consult resources and hear lectures and other forms of direct presentations. Another important finding is that giving students formative feedback and having them revise their work in light of that feedback can improve learning (Vye et al [20]). The SL Cycle includes opportunities for feedback and revision. Finally, the necessity of creating an authentic final product is motivating for students and allows them to practice applying what they have learned to a realistic situation they might face in an actual career setting (Barron et al. [21]). Thus, the SL Cycle can conclude with an opportunity to create an authentic product. The “go public” phase also might be a report or examination.

The SL Cycle is an efficient tool for designing challenge-based modules. First, using the SL Cycle gives students structure and makes it easier for professors to add the active aspects of HPL to the direct presentation strategies with which they are familiar and comfortable. Second, the HPL focus on knowledge-centered instruction has led to extensive efforts to integrate learning objectives and class activities (Diller & Martin [22], Roselli et al [23]). This effort helps achieve the goal that curriculum innovation should

integrate engineering knowledge. Third, computational environments for simulating and visualizing phenomena, and other computing approaches have been recently developed and used to increase student interest, learning, and feedback in mechanics and transport. The SL Cycle builds in these types of resources and promotes student learning.

EXPERIENCE IN VANATH WITH BIOMECHANICS AND BIOTRANSPORT

As part of VaNTH, Roselli transformed biomechanics and biotransport courses from traditional lecture-based courses to fully-implemented challenge-based courses [24,25]. Each course is based on 11-13 separate challenge-based modules. A three-year study was designed in biomechanics to determine the effectiveness of these HPL-inspired methods. Students in challenge-based classes did significantly better on 14% of domain-based questions designed to assess adaptive expertise, while students in traditional classes did significantly better on only 2% of the questions. Student surveys indicated that most students preferred the challenge-based approach compared to the traditional approach. The effectiveness of individual challenge-based modules and technological interventions were assessed using pre/post tests, student surveys and the VaNTH classroom observation system [26, 27, 28]. In-class formative assessment using an electronic classroom communication system (Personal Response System, PRS) was evaluated and shown to improve classroom participation. In addition, student performance was found to be related to class participation [25]. Pandy and colleagues also developed a challenge-based biomechanics course [29] and used the Jumping Jack module to develop a method for assessing adaptive expertise [30]. Freeman also implemented this course at the University of Texas Pan American [31,32]. Diller implemented a fully challenge-based biotransport course at the University of Texas [22], and is in the process of developing new assessment tools and extending the single module measurement of adaptive expertise to an entire course.

GENERAL APPROACH TO ASSESSMENT IN VANATH

In the studies conducted within VaNTH on effectiveness of HPL-inspired modules (and courses), the main hypothesis was that modules produce *greater* learning with understanding about bioengineering than traditional instructional strategies. Randomized experiments have long been regarded as the most trustworthy means of assessing the causal effect of an innovation [33]. When randomization of students to conditions is not feasible, a class of research designs known as quasi-experiments can be used to approximate estimates of effects [34, 35]. Approximately 50 modules have been developed throughout VaNTH; to date, 32 have been tested, using experimental or quasi-experimental designs to estimate the effects of the module on knowledge-based outcomes.

The modules tested within VaNTH, by design, differed in content. The nature of the assessment instrument was tailored to the content of each module, and to the research design that was used to assess relative effectiveness. In order to “sum-up” what was learned from this collection of investigations, meta-analysis methods were used [36,37]. Meta-analysis involves converting the study results into a common metric – known as an effect size (ES). The effect size is a descriptive statistic that expresses the difference between the means of the experimental and control groups on a learning outcome in standard deviation units [ES = $(M^T - M^C) / SD_{\text{pooled}}$ — the pooled standard deviations is the square root of the weighted variances within each condition]. Cohen [38] suggests that effect sizes of 0.20, 0.50 and 0.80 can be interpreted as representing small, medium and large effects, respectively. Converting each study result into this common metric provides a statistical basis for determining the overall effect of the HPL modules and provides a statistical basis for examining differences across VaNTH sponsored modules. The methodology used to sum up the overall effects of HPL-inspired modules and courses is described and illustrated in Cordray, et al. [39]

OVERALL EFFECTS OF HPL-INSPIRED MODULES

Preliminary effect sizes were calculated for 32 experiments and quasi-experiments on the effects of HPL-inspired modules and courses. These effect sizes ranged from -0.47 to 3.53 (standard deviation units) across the 32 studies. For this collection of studies, the weighted average effect is 0.685; that is, across all studies the average HPL mean was slightly over two-thirds of a standard deviation higher than the non-HPL means. The distribution of the effect sizes is presented in Figure 3. As can be seen, only two effects were negative. The remainder shows evidence of an advantage for HPL participants. However, as noted above, studies differed with respect to the type of design used and the type of comparison that was made to obtain the effect size estimate. More refined explanatory analyses [39, 40] are currently underway.

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