The Synergistic Impact of the VaNTH ERC on the Educational Practices of the School of Engineering and Computer Science at UTPA

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Abstract - **Six years of interaction with NSF's VaNTH ERC for Biomedical Engineering Educational Technologies has had a significant impact on how the Engineering faculty at UTPA, especially the Mechanical Engineering faculty, is addressing the common goal of producing proficient and adaptive engineers. Many of the principles and practices of VaNTH, including adherence to the How People Learn (HPL) framework for the design of effective learning environments, have informed not only curricular materials design but also an ongoing department level effort to reform the Mechanical Engineering undergraduate program of study. Beyond these more general adoptions and inspirations, our interaction with VaNTH has resulted in: 1) the development of seven HPL inspired undergraduate level learning modules designed according to the Legacy cycle implementation of challenge based learning (CBL), 2) involvement of high school students, as well as, undergraduate and graduate students in the development of learning modules, 3) development and implementation of a web delivered module containing adaptive learning activities, 4) delivery of a Biomechanics technical elective that would not otherwise have been offered, and 5) greater awareness of current practices in learning science and assessment. Each of these activities along with their broader impacts is described.**

Index Terms – Bioengineering education, educational collaboration, educational practices, integration across domains.

INTRODUCTION

The University of Texas-Pan American (UTPA) is the principal, post-secondary educational institution in the Rio Grande Valley. UTPA has a total enrollment of 17,000 students (87% Hispanic), many of which are the first in their families to attend college. The engineering program started in 1993 and now has the sixth largest enrollment of Hispanic engineering students in the nation, with 3 departments (Mechanical, Electrical, and Manufacturing) and a total of 829 undergraduate students (and 71 master's students) served by 30 faculty. A significant proportion of the students arrive at the University inadequately prepared to do college-level work, and it is a struggle to help them maintain their interest in and commitment to science and engineering, while developing their science, mathematics, and engineering skills. To this end the faculty are currently working on the development of integrative educational experiences and motivating activities [1] to support program objectives related to student retention, coverage depth, and development of student adaptive expertise. Interaction with VaNTH, a bioengineering educational research coalition formed by Vanderbilt, Northwestern, The University of Texas-Austin, and Harvard/MIT, and supported by the Engineering Research Center (ERC) program of the National Science Foundation (NSF) http://www.vanth.org, has significantly impacted the UTPA engineering programs' abilities to address these objectives by introducing us to the How People Learn (HPL) [2] framework for the design of effective learning environments and to a network of Learning Scientists and their current practices. In the following we briefly discuss VaNTH's impacts on the faculty, students, and school, followed by a description of the specific activities undertaken as a result of our interaction with VaNTH.

IMPACT ON FACULTY

The faculty started their interaction with VaNTH just over six years ago. At that time they had some interest in the application of their areas of expertise to the biomechanics domain, but no specific expertise in biomechanics. They were approached, as faculty at UTPA, to work on curricular module development in the area of biomechanics and to receive summer support to do so. In reality, it was the prospect of summer support that provided their initial motivation to join the project. However, the interaction with VaNTH biomechanics domain experts immediately peaked their interest in applying their related expertise to current problems in the area, and to the development of curricular modules concerning biomechanical engineering. Then, the interaction with VaNTH Learning Science faculty not only better informed them of current practices but provided them with a sounding board(s) for their ideas in how to design curricular innovations and to assess their effectiveness. They then introduced a new course in Biomechanics at UTPA comprised solely of their and other VaNTH curricular modules. In the course of teaching the modules developed by other VaNTH faculty they gained more expertise and interest in the area and have actively pursued creation of additional learning materials to enhance the effectiveness of these modules for their students.

IMPACT ON STUDENTS

Over the past six years, as noted in the module descriptions to come, four high school, nine undergraduate, and five graduate students have assisted the various faculty in the development of the curricular modules. In particular, two undergraduate students reproduced the Knee module in Spanish and two groups of second-year Upward Bound Math and Science Program high school students assisted in the development of a VRML simulation of a simple leg model to be used in a kinematics measurement module. Currently, there is one graduate student and two undergraduate students involved and we plan to enlist additional groups of Upward Bound Math and Science Program high school students to select modules for their research projects in summer 2006. In addition, over 150 students have participated in courses using the HPL curricular modules.

IMPACT ON THE SCHOOL OF ENGINEERING AND COMPUTER SCIENCE

The following illustrates some of the more general impacts of VaNTH principles and practices on the School of Engineering and Computer Science and, in particular, on the Department of Mechanical Engineering.

Mechanical Engineering Department Level Reform [3]

The emphasis of the recently initiated Mechanical Engineering department-wide curriculum reform program is the development of a four-dimensional (HPL), learner centered, knowledge centered, assessment centered, and community centered learning environment for the Department, as well as, for individual courses in the curriculum. This is a direct result of our partnership with VaNTH. Beyond that, many of the ideas for planning, developing, assessing, and disseminating the resulting curricular innovations are adapted from VaNTH guidelines. This intimate inclusion of VaNTH ideas and processes in departmental reform has and will have a significant and positive impact on all our faculty and students in terms of improved teaching and learning. Indeed, our interaction with the lead institution, Vanderbilt, has resulted in our inclusion in a CCLI dissemination proposal (pending) to develop HPL inspired, challenge-based, curriculum modules for the solid mechanics stem of Mechanical Engineering.

Curriculum Development Projects

VaNTH has established a systematic approach to the development and assessment of curricular innovations. This approach can be viewed as having three major components; a project development manual, an innovation design team, and an assessment strategy. The adopted aspects of these components are described below.

VaNTH Project Manual [4]

Two templates, Project Profile and Modular Design, adapted from original templates developed by the VaNTH ERC, are being used to help develop and disseminate educational innovations and/or student learning experiences. The Project Profile (Figure 1) provides an outline of information needed to give sufficient snapshot of the project to other faculty who may be interested in adopting the project or even participating in its development. The Design template (Figure 2) provides a workspace to articulate the response to the many driving questions for sequencing interrelated projects, laboratories, and competitions; computer-based instruction; advance material and elective work; and integration of research and education. It provides a structure for defining important information necessary for the other design team members and other faculty and consultants to provide input about the design. For instance, objectives are defined in explicit measurable terms for what a student will be able to do during and at the end of each sequence. Both knowledge and ABET core competencies are considered. In addition, this same information is important to future users of these materials and future designers of similar materials.

Project Profile
Project Name
Project Director: *Director Name and e-mail*
Project Participants: *Participant Names*
Contents
Audience
Learning objectives
Sequence of learning activities
Innovations
Placement in the taxonomy
Assessment
Dissemination timetable
References
Revised: *April 1,2005*
If you are interested in adopting this material, please contact the project director.

FIGURE 1. PROJECT PROFILE TEMPLATE (ORIGINAL TEMPLATE BY THE VANTH ERC)

Curriculum Design Teams

Another critical component for the development of effective curricula is the establishment of a design team for each educational innovation comprised of a Learning Scientist (LS), Assessment and Evaluation expert (AE), Learning Technology expert (LT), and Domain expert. This is being adopted based on the success of this practice experienced within VaNTH and has resulted in our enlistment of UTPA faculty in the Department of Curriculum and Instruction and the Director of the Center for Distance Learning and Teaching Excellence onto our innovation development teams.

Curriculum Effectiveness

The involvement in VaNTH has enabled a more rapid incorporation of current learning science practices into our curricular design efforts. Beyond being informed of the HPL effective learning environment structure and its implementation via the Legacy cycle (see below), our involvement has given us direct personal interaction with numerous experts in LS & AE, allowing us to pick up the phone and discuss ideas with these individuals and have immediate access to their expertise. This not only saves time but helps clarify the goals of the planned innovation, with the expert effectively serving as a consultant to the design team. Another important result of our interaction has been the awareness of the importance of integrating the design of assessment with the design of the curriculum. This really forces one to design the curriculum to address the desired learning objectives, as well as to clearly establish what those objectives are. Also, one of the practices VaNTH employs to

Modular Design Template
Mechanical Engineering Program of Study-UTPA

A. Sequence Description
- A1. General Information
  - A11. Project Title
  - A12. Keywords to describe sequence content/skills
  - A13. Project leader and member of design team (LS, AE, LT)
  - A14. Course numbers, names, and fraction of the overall sequence covered
- A2. Sequence Background
  - A21. Brief course descriptions (catalog style)
  - A22. Target student population
  - A23. Attach course syllabi
  - A24. Identify major course objectives
  - A25. Identify sub-objectives necessary for achieving the major course objectives
- A3. Describing Instructional Innovation/Experience
  - A31. Identifying Objectives of Educational Innovation/Student Learning Experience
  - A32. Identify scientific/technical content targeted by the learning activities (what areas of the sequence taxonomy are addressed)
  - A33. Identify potential integration with other courses and domains

B. Identifying Student Needs
- B1. Identify learning obstacles students often have related to technical area of sequence addressed by innovation/experience
- B2. Theory for pedagogical/cultural issues and possible solutions for difficulties
- B3. Identify evidence to determine success

C. Designing Instruction
- C1. Describe potential innovation/experience statements that target the combination of concepts
- C2. Research and revise type of activities that support students' learning of specific concepts related to the innovation/experience
- C3. Test and refine activities that encourage students to display what they have learned and methods used to help them evaluate and refine their current abilities

D. Identifying Implementation Issues
- D1. Special equipment or infrastructural resources are necessary in order to achieve the learning outcomes

E. Evaluation and Assessing Plan for the Project
- E1. Assessing Student Learning

FIGURE 2. ADAPTED MODULAR DESIGN TEMPLATE (ORIGINAL TEMPLATE BY THE VANTH ERC)

assess the effectiveness of the classroom implementation of curricular practice is the VaNTH Observation System [5]. This involves an external observer coding the effect on student behavior of classroom activity. We intend to enlist VOS trained personnel to observe various courses and provide feedback not only to the course instructors but also to the faculty as a whole in an effort to inform the faculty on effective in-class activities.

SPECIFIC ACTIVITIES

Locally Developed Biomechanics Learning Modules

Six faculty have been involved in HPL inspired, challenge/problem based learning module development, four in Mechanical Engineering and one each in Electrical and Manufacturing Engineering. These modules are structured according to the Legacy learning cycle [6] which is based on a sequence of contextually related challenges of increasing difficulty. This structure is common to many VaNTH curricular modules. A brief description of this cycle is given below in outline format. Note that with embedded assessments the entire cycle is *assessment centered*. Summaries of the goals and status for each of the locally developed modules follow the Legacy cycle description.

Legacy Cycle

Look ahead: The learning task and desired knowledge outcomes are described here. This step also allows for pre-assessment and serves as a benchmark for self-assessment in the Reflect Back step.

Challenge 1: The first challenge is a lower difficulty level problem dealing with the topic. The student is provided with information needed to understand the challenge. The steps shown below represent the remainder of the cycle, which prepares the students to complete the challenge.

- a. **Generate ideas**: Students are asked to generate a list of issues and answers that they think are relevant to the challenge; to share ideas with fellow students; and to appreciate which ideas are "new" and to revise their list. *Learner and community centered.*
- b. **Multiple perspectives**: The student is asked to elicit ideas and approaches concerning this challenge from "experts. *Community centered.*
- c. **Research and revise**: Reference materials to help the student reach the goals of exploring the challenge and to revise their original ideas are introduced here. *Knowledge centered.*
- d. **Test your mettle**: Summative instructional events are now presented. *Knowledge centered.*
- e. **Go public**: This is a high stakes motivating component introduced to motivate the student to do well. *Learner centered.*

Challenge 2…N: The following progressively more ambitious challenges enable the student to progressively deepen their knowledge of the topic being explored. They are to repeat the complete cycle (a-e) for each challenge.

Reflect back: This gives student the opportunity for self-assessment. *Learner centered.*

Leaving Legacies: The student is asked to provide solutions and insights for learning to the next cohort of students, as well as to the instructor(s). *Community centered.*

Biomechanical Model-Based Control of a Human Leg

- **Module Developer:** Dr. Mounir BenGhalia, Associate Professor of Electrical Engineering
- **Targeted Course(s):** ELEE 4321, Automatic Control & ELEE 4333, Rapid Control Prototyping
- **Web link:** http://w3.panam.edu/~benghalia/automatic
- **Goal:** A first challenge for students taking a control systems course is to draw a block diagram to represent a control process. One of the main difficulties of this task is identifying the actuating signals and the response (output) signals. Control applications discussed in a typical undergraduate control system course or those that can be found in control systems textbooks deal with man-made systems and processes. The main goal of this module is to introduce students to a biological control application consisting of the modeling and control of a human leg.
- **Status:** Learning materials implemented Spring 2006

Anaerobic and Muscle Work Capacity Development and Retention Models

- **Module Developer:** Dr. Miguel Gonzalez, Associate Professor of Manufacturing Engineering
- **Targeted Course(s):** MANE 2340, Fundamentals of Industrial Engineering & MANE 3332, Engineering Statistics
- **WebLink:** **http://www.engr.panam.edu/~mgonzale/**
- **Goal:** The primary goal of this project is to develop one module (Aerobic and Anaerobic Work Capacity) to promote students' understanding of the concepts of development and retention of aerobic and anaerobic work capacities for the human body, and one module (Muscle Static Work Capacity) to promote students' understanding of the development and retention of muscle work capacity.
- **Status:** Module complete and implemented spring 2006.

Biomaterial Selection for Implant Design

- **Module Developer:** Dr. Robert Jones, Associate Professor of Mechanical Engineering, and Dr. Mauli Agrawal (UTHSC-SA)
- **Targeted Course(s):** MECE 2440, Engineering Materials
- **Web Link:** **http://www.engr.panam.edu/~rjones**
- **Goal:** The goal of this project is to provide a framework for students to extend their existing knowledge of materials engineering derived from a classical Materials Science course by introducing the distinctive attributes required of materials in a biological environment. Students also need to be introduced to the manner in which distinctive problems in biological systems affect the selection and development of materials for engineering applications.
- **Status:** Learning materials implemented, module to be implemented Fall 2006

Human Knee Joint Mechanics

- **Module Developer:** Dr. Robert Freeman, Professor of Mechanical Engineering
- **Targeted Course(s):** MECE 4333, Introduction to Computational Biomechanics & MECE 3380, Kinematics and Dynamics of Machines
- **WebLink:** **www.engr.panam.edu/~rafree/IntroBioMech/BioMechModules/The Knee/**
- **Goal:** The goal of the project in which the Knee Joint module is a component is to develop granules and modules for the investigation of the **mechanics of the human upper and lower extremities**. Currently, focus is on the continuing development of a human knee joint module based on the cruciate linkage model of the tibiofemoral joint with a single point model of the patellofemoral joint.
- **Status:** Two challenges completed. Web version implemented twice at UT-Austin and twice at UTPA. CAPE version tested at UTPA spring 2006.

Solid Mechanics Module

- **Module Developer:** Dr. Arturo Fuentes, Assistant Professor of Mechanical Engineering
- **Targeted Course(s):** MECE 3321, Mechanics of Solids & MECE 4322, Introduction to the Practice of Finite Elements
- **Web Link:** **www.engr.panam.edu/~afuentes/fea**
- **Goal:** The goal of the project is to develop a module to illustrate the relationship between “classical mechanics of solids” and “finite element” stress analysis.
- **Status:** Learning materials implemented, module to be implemented Fall 2006

Skeletal Representation

- **Module Developer:** Dr. Stephen Crown, Associate Professor of Mechanical Engineering
- **Targeted Course(s):** MECE 1221, Engineering Graphics
- **Web Link:** **www.crown.panam.edu/EG**
- **Goal:** The goal of the project is to develop a module to create a computer graphics model of the human skeleton (leg)
- **Status:** Under development

Motion Measurement

- **Module Developer:** Dr. Stephen Crown, Associate Professor of Mechanical Engineering
- **Targeted Course(s):** MECE 3320, Measurements and Instrumentation
- **Web Link:** www.crown.panam.edu/measurements
- **Goal:** The goal of the project is to develop a module to use standard engineering data acquisition systems to measure human body (leg) motion
- **Status:** Materials to be tested Fall 2006

Virtual World delivery Environment

- **Module Developer:** Dr. Stephen Crown, Associate Professor of Mechanical Engineering
- **Targeted Course(s):** None, faculty resource
- **Web Link:** www.crown.panam.edu/toolbox
- **Goal:** The goal of the project is to develop a module to provide tools for faculty development of an interactive web-based environment (VRML) for the delivery of certain VaNTH materials
- **Status:** Tools available, module under development

Note that the modules may be used in other disciplines related to biomechanics where the content taxonomies overlap.

VaNTH Curricular Module Implementation

We are also planning to implement and assess existing VaNTH biomechanics modules in various traditional undergraduate Mechanical Engineering (ME) courses. Table I shown below gives an initial listing of VaNTH modules and the Engineering courses in which they will be implemented and assessed. A research question associated with this activity is; Can tradition ME concepts be successfully taught within the context of biomechanics applications? An additional, and perhaps more significant, question is; Does the teaching of traditional ME concepts out of their normal context assist the development of student adaptive expertise? The answers to these questions are awaiting further implementation and assessment.

TABLE I
VANTH MODULE IMPLEMENTATION IN TRADITIONAL ME COURSES AT UTPA

Module/ Original Development Site	**Course/Title**	**Dept. / Required**	**Semester/ # of Students**	**Assessments**
Iron Cross / Vanderbilt	MECE 2301/ Statics	ME & MANE/ Req.-Yes	F06, Sp07/ 45 per semester	Pre- and Post-Quizzes
Jumping Jack C1/ UTAustin	MECE 2302/ Dynamics	ME & MANE/ Req.-Yes	F06, Sp07/ 45 per semester	Pre- and Post-Quizzes
Soccer Injury/ Vanderbilt	MECE 3321/ Mech. of Solids	ME & MANE/ Req.-Yes	F06, Sp07/ 45 per semester	Pre- and Post-Quizzes
Jumping Jack C2a/ UTAustin	MECE 3380/ Kin. & Dyn. of Machines	ME/ Req.-Yes	F06,07/ 60 per semester	Pre- and Post-Quizzes
Jumping Jack C2b/ UTAustin	MECE 4304/ Auto. Control Systems	ME / Req.-No	Sp07/ 15 per semester	Pre- and Post-Quizzes

Human Knee Module: CAPE** [7] **authored, eLMS** [7] **delivered

The CAPE version of the Knee module mimics the standard web delivered Legacy cycle version in that the upper level, of the CAPE module are the steps of the Legacy cycle. Figure 3 shows the upper level of the CAPE version of the module. The CAPE version differs significantly from the standard web version in that there are embedded adaptive learning activities in the Generate Ideas, Multiple Perspectives, and Research & Revise phases / steps that can not be included in a non-managed web page delivery. Furthermore, eLMS keeps a delivery record that enables the instructor to see exactly how the student(s) traversed the module and, in particular, to see their performance in the formative adaptive learning activities. This ability allows the instructor to discover common misconceptions and problems and underscores which areas of the module need improvement. Figure 4 shows the second layer of the Research & Revise phase, along with adaptive learning activities, for delivery via eLMS. Depending on the student's responses to the "quiz" they are directed to the appropriate review materials.

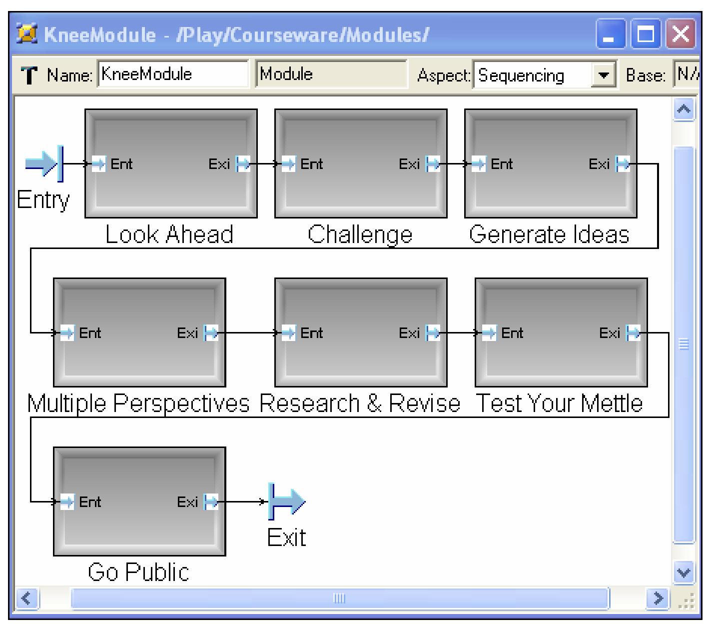

FIGURE 3. CAPE VERSION OF THE KNEE MODULE

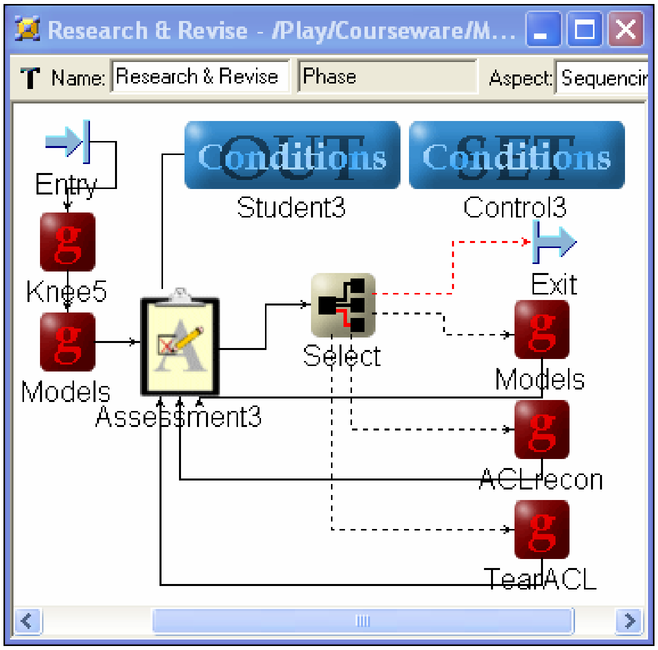

FIGURE 4. RESEARCH & REVISE WITH ADAPTIVE LEARNING ACTIVITIES

The development of this CAPE/eLMS version would, of course, not have been possible without the existence of these learning technologies as developed within VaNTH nor without the assistance of their developers.

Biomechanics Technical Elective: Introduction to Computational Biomechanics

This course is designed to introduce the anatomy and functional anatomy of the human upper and lower extremities. The course material is solely comprised of VaNTH modules including; the Iron Cross (IC) module (two challenges) originally developed at Vanderbilt University, the Virtual Biomechanics Laboratory module (three challenges) and the Jumping Jack module (three challenges) originally developed at The University of Texas at Austin, and the locally developed Knee Joint module (three challenges). It is important to note that without our interaction with VaNTH and the existence of the VaNTH Biomechanics curricular modules it would not have been feasible to offer this course at UTPA. Another important consequence of our teaching this course is the generation of additional reference materials, simulation granules, and even new challenges (one for the IC and one for the JJ) that have and are being disseminated to the original developers of the modules. The course is now offered every Spring semester for the foreseeable future. The pre- and post-tests and their scoring rubrics are the same as for a course offered at UT-Austin [8], [9]. This will enable VaNTH assessment experts to answer the question; Are the VaNTH HPL concepts as effective in a university setting such as UTPA as they were at VU, NWU and UT-Austin? Comparative assessment of the results of pretests and posttests given to both UTPA's spring 2005 and UT-Austin's fall 2004 version of this class showed that a greater effect size ($ES=(\mu_{post} - \mu_{pre})/\sigma_{pooled}$) was obtained by UTPA in three of the four modules and for the overall course.

CONCLUSION

Partnership with VaNTH lead to our awareness and adoption of the How People Learn principles for the design of effective learning environments and has greatly impacted several educational initiatives in the different engineering programs at The University of Texas - Pan American. In particular, VaNTH's implementation of HPL learning environment design via a systematic approach to the development and assessment of curricular innovations is providing guidance to a department level reform effort, and to the development of new courses and curricular modules in traditional areas of engineering as well as in biomechanics.

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REFERENCES

[1] Fuentes, A.A., Crown, and S., Freeman, R., "Selective Integration for Student Motivation in the Mechanical Engineering Educational First-Year Experience for Underrepresented and First Generation Students", *9th International Conference on Engineering Education, San Juan, PR., 2006*

[2] Bransford, J. D., Brown, A. L., and Cocking, R. R. (Eds.), "How People Learn: Brain, Mind, Experience, and School, National Research Council, National Academy Press, Washington, D.C., (1999).

[3] Fuentes, A.A., Crown, S., Freeman, R.A., Kypuros, J., and Mahdi, H., "Desegregated Learning: An Innovative Framework for Programs of Study" , *J. New Directions for Teaching and Learning*, Jossey-Bass, 2005.

[4] Brophy, S.B, Linsenmeier, R.A. and Harris, T. R. , "VaNTH Bioengineerng Domain Project Manual", http://www.vanth.org/white_papers.html

[5] Harris, A.H. and Cox, M.F., "Developing an Observation System to Capture Instructional Differences in Engineering Classrooms", *Journal of Engineering Education* 92: 329-336, 2003.

[6] Brophy, S.P. and Bransford, J, "Design Methods for Instructional Modules in Bioengineering. ", *Proceedings of the American Society for Engineering Education* (2001). Session 1609: 11 pages. CD-ROM. Mira Digital Publishing, Inc.

[7] Howard, L., "CAPE: A Visual Language for Courseware Authoring", *Second Workshop on Domain-Specific Visual Languages*, Seattle, WA, November 4, 2002.

[8] Barr, R, Pandy, M, Petrosino, A, Austin, B and Goldberg, E. "Classroom Testing of VaNTH Biomechanics Learning Modules. ", *Proceedings of the American Society for Engineering Education* Session 1109: 20 pages (2004).

[9] Barr, RE, Pandy,MG, Petrosino, AJ, Roselli, RJ, Brophy, S, and Freeman, RA, "The VaNTH Biomechanics Learning Modules", *The 4th Global Colloquium on Engineering Education*, Sept. 26-29, 2005, Sydney, Australia.