AC 2011-1721: DEVELOPMENT AND IMPLEMENTATION OF INTRODUCTION TO MECHANICAL ENGINEERING CHALLENGE-BASED INSTRUCTION TO INCREASE STUDENT RETENTION AND ENGAGEMENT

Arturo A Fuentes, University of Texas, Pan American

Dr. Arturo Fuentes is an associate professor of Mechanical Engineering at the University of Texas - Pan American. He received his Masters and PhD in Mechanical Engineering from Rice University. His current research interests are in the areas of engineering education, nanofiber reinforced composites, non-destructive evaluation, and finite element analysis.

Horacio Vasquez, University of Texas, Pan American

Dr. Horacio Vasquez is an Assistant Professor in the Mechanical Engineering Department at the University of Texas-Pan American (UTPA), in Edinburg, Texas. His current research interests are in the areas of control systems, mechatronics, measurements and instrumentation, renewable energy, and engineering education.

Robert A. Freeman, University of Texas, Pan American

Dr. Robert A. Freeman has been on the faculty of The University of Texas System for over 25 years and is currently Professor and Chair of the Department of Mechanical Engineering at UTPA. His research interests include; Kinematic and dynamic modeling, analysis, design and control of multi-rigid-body linkage systems; Robotics; Biomechanics; and Engineering education.

Development and Implementation of Introduction to Mechanical Engineering Challenge-Based Instruction to Increase Student Retention and Engagement

Abstract

This paper discusses a series of introduction to mechanical engineering challenges developed and implemented to increase student retention and engagement in a freshman engineering course. Studies have shown that freshman or sophomore intellectual experiences play a decisive role in Science, Engineering and Mathematics (SEM) student retention and that minority SEM students, among others, leave SEM undergraduate fields in part due to lack of real world connections to their classroom learning experiences. Introduction to Mechanical Engineering is a course that introduces mechanical and civil engineering students to the engineering college education and profession. The challenge-based instruction (CBI) curriculum developed for Introduction to Mechanical Engineering includes challenges, lecture and handout materials, hands-on activities, and assessment tools. CBI is a form of inquiry based learning which can be thought of as teaching backwards strategy. When implementing CBI, a challenge is presented first, and the supporting theory required to solve the challenge is presented second. CBI was built around the How People Learn (HPL) framework for effective learning environments and is realized and anchored by the STAR Legacy Cycle, as developed and fostered by the VaNTH NSF ERC for Bioengineering Educational Technologies. The CBI instruction was developed and implemented in the areas of reverse engineering, statics, dynamics, energy (including renewable energy), and forward engineering. Additionally, the paper describes the initial impact of the CBI curriculum on the students, including initial assessment results, and the impact on the faculty and the course. A controlled experiment was performed with a control group following a more traditional laboratory setup. From the initial positive results obtained in this project, it is argued that the VaNTH principles are effective in motivating and engaging freshman engineering students in mechanical and civil engineering majors and that the CBI materials and tools developed for this course could support other institutions' efforts in student attraction, retention, and engagement. This project was supported by a College Cost Reduction and Access Act (CCRAA) grant from the Department of Education that focuses on student retention and development of adaptive expertise.

Introduction

Increasing student attraction and retention in Science, Technology, Engineering, and Mathematics (STEM) fields is important for the U.S. competitiveness in the global market. Research consistently points to the importance of freshman and sophomore curriculum and/or intellectual experiences to retain undergraduate SEM students[1]. Seymour and Hewitt[1] conducted a study to determine the relative importance of key factors which undergraduates reported as impacting their decision to continue in or transfer out SEM courses. Among other things, they discovered that the primary student concerns were pedagogical, including concerns related to curriculum design and assessment[1]. Specifically, they found talented students, at each of the seven participating institutions, who switch from SEM courses because they felt understimulated by their freshman or sophomore intellectual experiences and felt drawn to explore other interest[1].

Research also points to the student need to see the relevance of their studies to the real world. In fact, the perceived lack of relevance to the real world was listed as one of four key reasons for minority STEM students' decision to drop-out or transfer out of STEM undergraduate fields of study[2]. While the need to relate their studies to the real world is important to all the students, it becomes decisive for minority students because they lack of an equitable number of career influencers and role models within their families and familiar networks. When minority students select STEM fields of study, they experience an immediate need to confirm the relevance and compatibility of their studies and seek real world connections to their classroom learning experiences - connections that they do not find in the traditional classroom[2].

This paper discusses a series of introduction to mechanical engineering challenges developed and implemented to increase minority student retention and engagement. While the target population of the project was minority Hispanic students, the freshman intellectual experience was designed for any student regardless of ethnicity (i.e. universal design). This project is part of a large two-year Department of Education College Cost Reduction and Access Act (CCRAA) grant. This initiative is a collaboration between The University of Texas – Pan American (UTPA) and South Texas College (STC), a two-year community college, to facilitate student engagement and success in STEM areas. Both UTPA and STC are Hispanic Serving Institutions (HSIs). Some other activities and results of this CCRAA grant have been described in previous papers[3,4].

Challenge Based Instruction

The selected pedagogical approach was Challenge Based Instruction (CBI) based on the principles of "How People Learn" (HPL) and the STAR Legacy cycle (LC). CBI, as project-based learning (PBL), is a form of inductive learning. CBI has been shown to be a more effective approach to the learning process than the traditional deductive pedagogy[4-6] and incorporates cognitive and affective elements recommended for retaining underrepresented students[7-9]. CBI provides a real life learning environment where the challenge/problem is introduced first and the supporting theory/principles second (i.e. traditional teaching backwards)[10]. Thus, by directly addressing students' need to see Relevance of Studies to the Real World and creating a stimulating intellectual experience, CBI addresses student retention and engagement. Furthermore, instruction based on realistic challenges implemented with opportunities to attempt difficult problems independently and receive resources and lectures to help in the learning process, increases both students' innovation and efficiency[11]. This is important since SEM students and professionals need to be able to adapt as opportunities and applications as these fields evolve[10].

CBI is implemented in the form of a slightly modified STAR Legacy Cycle[12]. This cycle "is an exemplar of an inductive approach to teaching and learning"[13] and contains a directed sequence of steps that immerses the learner in the four dimensions of the HPL effective learning environment and provides a framework for CBI and the design of associated learning activities[14]. The cycle is illustrated in figure 1 and it is briefly described next[10]. The legacy cycle contains steps or activities that appeal to different learning styles[13] and most of those activities align themselves nicely with key phases of the engineering design process[15].

Figure 1. Legacy Cycle and Engineering Design Process

The LC consists of the process followed to solve challenges that are designed to motivate and engage students in learning activities. In the LC, the following steps are performed and repeated:

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 (shown in Figure 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. Note that formative instructional events can and probably should occur in each step of the cycle. The following LC steps are to motivate and engage the students:

- 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.*
- Multiple perspectives: The student is asked to elicit ideas and approaches concerning this challenge from "experts." *Community and knowledge centered.*
- 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 and learner centered.*
- Test your mettle: Summative instructional events are now presented. *Knowledge and learner centered.*

- Go public: This is a high stakes motivating component introduced to motivate the student to do well. *Learner and community centered.*

Challenge 2…N
The following progressively more ambitious challenges enable the student to increasingly deepen their knowledge of the topic being explored. Repeat the complete legacy cycle 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.*

Curriculum Development Process

In general, the LC CBI modules developed at UTPA are designed according to a five-task "backwards design" process fostered by VaNTH and based on Wiggins and McTighe's *Understanding by Design*[16]. The planning phase is composed of the first three tasks of Defining Objectives / Outcomes, Creating a Model of Knowledge, and Determining Evidence. The implementation phase is composed of tasks four and five, Selecting / Developing Materials, and Selecting / Providing Delivery.

As stated in the VaNTH "Workshop on Designing Effective Instruction" 2009 manual, these tasks involve the following activities. Defining Objectives involves identifying the objectives, sub-objectives, potential difficulties in accomplishing those objectives, and real-world applications of the objectives[10]. Creating a Model of Knowledge involves identifying concepts and skills involved in the challenge and how they relate to one another (i.e., creating a concept map), prioritizing the concepts and skills into the categories of Enduring Understanding, Important to Know and Do, and Worth Being Familiar With. Determining Evidence involves reviewing the objectives to determine acceptable evidence and planning the assessments to be used (e.g., Formative assessments for the LC Test Your Mettle step, and Summative assessments for the LC Go Public step). In light of the adopted LC approach, Selecting / Developing Materials involves designing effective real-world challenges (LC Challenge Question) to engage the students with the desired content and then selecting / developing learning materials to help the students master the concepts (e.g., through lecture, simulation, video, experiment, etc. in the LC Multiple Perspectives and Research and Revise steps). Finally, Selecting / Providing Delivery involves determining how these materials should be delivered (e.g., listening to a live lecture, observing a simulation, reading an assigned text, viewing a video, etc.). In the next section, an overview of the Legacy Cycle is presented with example challenges.

Challenges in Introduction to Mechanical Engineering

The challenges developed and implemented for Introduction to Mechanical Engineering are presented in Figure 2 organized in CBI modules. Some of these challenges were also envisioned for use in a Introduction to STEM Course for Dual-Enrollment Programs[17]. The Design of Experiments challenge marked with a "*" has not been implemented yet at UTPA. All the challenges shown have hands-on activities as part of the *research and revise, test you mettle*, and *go public* parts of the Star Legacy Cycle.

- M1. Reverse Engineering Design Module
  - Power Tool Challenge
- M2. Engineering Mechanics: Statics Module
  - Bridge Failure Challenge
- M3. Engineering Mechanics: Dynamics Module
  - Dynamics: linear motion and collisions
- M4. Energy Module
  - Energy Audit & Renewable Energy
- M5. Design of Experiments Module*
- M6. Forward Engineering Design Module
  - Spaghetti Bridge Challenge

Figure 2. Challenges Developed for the Introduction to Engineering Course

The existing modules cover almost 80% of the material of the course. Figure 3 shows the mapping of the modules to the objectives of the course. The student challenges take place in the Measurements and Instrumentation lab equipped with work tables and computers. The majority of the challenges were initially implemented in Fall 2009. The challenges are performed during two 75-minute classes. Besides the modules, the course contains activities and lectures in a classroom or computer laboratory in topics such as profile of the engineering profession and education, systems of units, data presentation and graphing, ethics, and problem solving using common engineering concepts.

A description of one of these challenges is presented next to demonstrate the challenge development and implementation process, the developed instructive materials, assessment tools (pre-test and post test), and the preliminary results that were obtained in the implementation of the challenges. Similar instruction and assessment tools were developed for each of the other challenges in Figure 2.

Introduction to ME Objectives	M1	M2	M3	M4	M5	M6
Engineering Profession	■					
Engineering Problem Solving		■	■	■		■
Engineering Measurement and Estimations	■	■	■			■
Engineering Units, Dimensions and Conversions	■					
Engineering Design / Legacy Cycle / Manufacturing	■				■	■
Engineering Teamwork Skills	■	■	■			■
Engineering Software and Instrumentation		■	■	■		
Engineering Technical Data Presentation		■	■		■	
Basic Electrical Theory				■		
Basic Mechanics		■	■			
Basic Engineering Economics				■		
Basic Statistics					■	
Basic Energy Concepts				■		
Basic Chemistry						
Engineering Ethics & Safety				■	■	

Figure 3. Mapping of the CBI Modules to Objectives of the Introduction to Mech. Engineering

Challenge Development Example: Bridge Failure Challenge

In general, to develop challenges for Introduction to Mechanical Engineering, the authors took a backward design approach (see curriculum development process section). The process started with identifying all the target concepts that students needed to learn and understand by the end of the challenge. Then, the objectives, sub-objectives, difficulties, and real-world applications and contexts were specified. This development process for the bridge failure challenge is presented below:

- *Primary Objectives*
  By the next class period students will be able to:
  - Explain the engineering design process
  - Understand and explain the concept of tension/compression
  - Understand and explain the importance of load placement
  - Understand the design of a truss bridge
  - Design and construct prototypes
  - Function in diverse teams
  - Document results and conclusions
  - Understand and use basic engineering instrumentation and software
  - Understand and use engineering data presentation tools (graphs and tables)
  - Understand and use dimension and units
  - Perform unit conversions
- *Sub Objectives*
  The objectives will require that students be able to:
  - Understand brainstorm process
  - Understand and use basic engineering instrumentation and software

    - Understand and use engineering data presentation tools (graphs and tables)
    - Understand and use dimension and units
    - Perform unit conversions
- *Difficulties*
  Students have difficulty understanding the concepts of tension and compression and the effects that different loading conditions cause on truss links and their supports. They usually benefit from reviewing and practicing concepts related to the engineering design process and teamwork skills in a real engineering context.
- *Real-World Contexts*
  The introduction of mechanics fundamentals to students early in their careers allows them to connect their current knowledge to engineering applications. The mechanics knowledge gained provides a foundation and motivation to many courses in the mechanical, civil, and industrial engineering curriculum.

Then, the authors had to categorize and prioritize the target concepts of the different challenges. This process is illustrated below for the bridge failure challenge:

- *Concept Map*
    - Engineering Design Process
        - Role of prototype/model testing and validation
    - Truss Bridge
        - Tension
        - Compression
    - Prototype Construction and Instrumentation
    - Teamwork Skills
        - Brainstorming skills
    - Engineering Documentation
- *Content Priorities*
    - Enduring Understanding
        - Tension and compression concepts, units, dimensions, unit conversion
    - Important to Do and Know
        - Teamwork skills
    - Worth Being Familiar with
        - Software and instrumentation

Finally, a plan was created to develop the assessment tools required to collect information that allows generating conclusions about student learning and understanding of the targeted concepts. As an example, the assessment plan for the bridge failure challenge is presented below:

- *Formative Assessment*
    - Pre-test
    - In class activity(groups)
        - Worksheet
    - Homework (individual)
        - Report
        - Quiz

- *Summative Assessment*
    - Post-test
    - Affect Survey/Student Evaluations
    - Exams

Challenge Implementation Example: Bridge Failure Challenge

In general, the process of implementation consisted in the following steps. At the beginning of the class period, a 5-minute pre-test was given and the challenge was handed out to the students and presented to the class in a power-point presentation. Then, students proceeded to generate ideas during a 10-minute period. After that, for about 25 minutes, the instructor clarified student misconceptions and presented a lecture with some examples and information about the challenge concepts. After suggesting the teams a specific path of action, hand-on activities were introduced along their goals and procedures. Students received handouts with additional background information and, if necessary, lab procedures. Students review the information in the handout, identify the equipment and components required for the hands-on activity, and perform the experiments. Finally, students prepare their conclusions and present the results and solutions to the challenge. At the following class period, a 5-minute post-test was given to the students for some of the challenges. The implementation process for the Bridge failure challenge is presented below:

Challenge

In general, challenges were design to motivate and engage students in the learning process by, among other things, assigning them responsibilities' and tasks related to real-world situations. Figure 4 presents the Bridge Failure challenge statement.

Bridge Failure Challenge

Your company's' bridge has failed and it is your job as the new design engineer to determine what could have caused the failure of the bridge and, as much as possible, defend the company. Is your company liable for the accident?

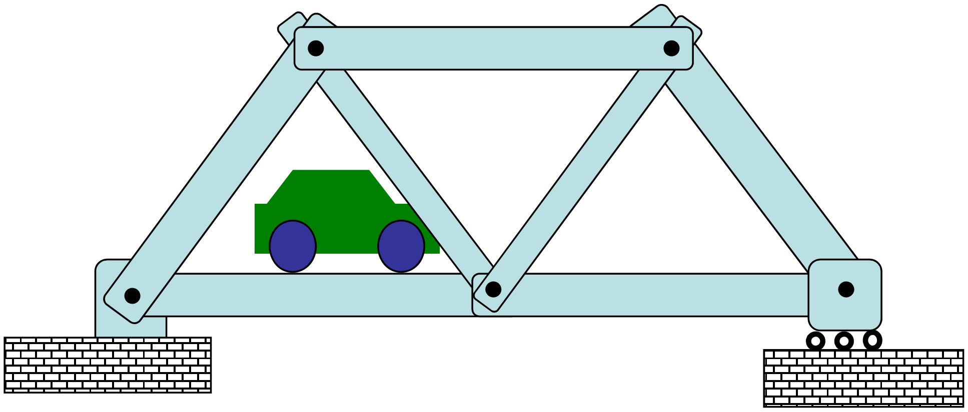


Figure 4. Statement for Bridge Failure Challenge

Generate Ideas

A student handout was used to request students to brainstorm and write ideas about the challenge. The handout tells the students that their supervisor will meet with them shortly to hear their initial thoughts, to answer any questions that they might have, and to share information. Students know that the information and conclusions they provide would be used as testimony by the company in a court of law. Furthermore, the handout included questions about the importance of finding the solution, the process to reach a solution, difficulties, and limitations. It also provided space for the students to generate questions about the challenge. Students work alone for the first few minutes then they are allowed to interact and share ideas with their group members to avoid any biased ideas on each other.

Multiple Perspectives

After the student provided different case scenarios including overload, accidents, natural disasters, design errors, manufacturing errors, material quality issues, etc., the instructor clarified any misconceptions they had during generating ideas. After that, students are guided in the direction the instructor would like them to follow in order to reach a solution to the challenge (e.g. overload reason for bridge failure) but without directly giving or stating the solution. Students add more ideas and any misconceptions are clarified and eliminated. Based on the overload scenario, students received a handout in which they are asked to begin answering questions such as: how much load (and the type of load: tension or compression) is transferred to each member of the truss bridge structure when loads are placed at key points of the structure? , what are the different ways of determining the internal forces in the bridge links?, and what are the key locations of the structure where the load have to be applied to replicate worst real-world conditions?

Research and Revise

A formal presentation was given to the students about trusses and their importance in real-life applications. This presentation includes the state of tension and compression in structural elements. Handouts are given to students to support the presentation and provide additional reading materials and references.

At this point in time, the handout is discussed. The students are directed towards building a prototype and instrumenting the prototype to obtain information that may be useful to compare and understand the bridge failure. Student are giving the design of the bridge that failed, the materials to create the prototype (bridge set materials), and a handout to with instructions on how to instrument the bridge with sensors and use the software to acquire data.

During the experimental part, more questions are asked to the students to reflect on the process that they will follow to test the bridge and reach conclusions. They included the following: do you need to test different loads and do you need to determine load at all the bridge members?

Test Your Mettle

At the beginning of the second day of the challenge, the handout is reviewed to provide additional instructions and clarify any doubts students might have. Students are given the opportunity to collect data by rationalizing what members should be tested with the load cells. Figure 5 shows students in the process of collecting information. Figure 6 shows part of the handout designed for students to complete a section of the “Test Your Mettle” step of the legacy cycle. Students also test their mettle by analyzing the bridge and making sense of the force values they obtained whether negative or positive (i.e. tension or compression). If time allows, the idea of determining the force reactions at the foundations of the bridge is hinted to the students. In another section of the lab activity, students observe the change in load magnitude in some of the bridge links as a cart moves from one end to the other end of the bridge. The objective of this part of the lab is for the students to take the information observed and represent it in a graphical way and to eliminate any misconceptions they might have about reaction forces and the way the load affect the links as the cart moves from end to end. Furthermore, if time allows, students are giving the opportunity to construct alternative bridge designs; but, they are ultimately led to consider two additional truss bridge designs included an inverted bridge configuration (i.e. with the truss structure under the road level).

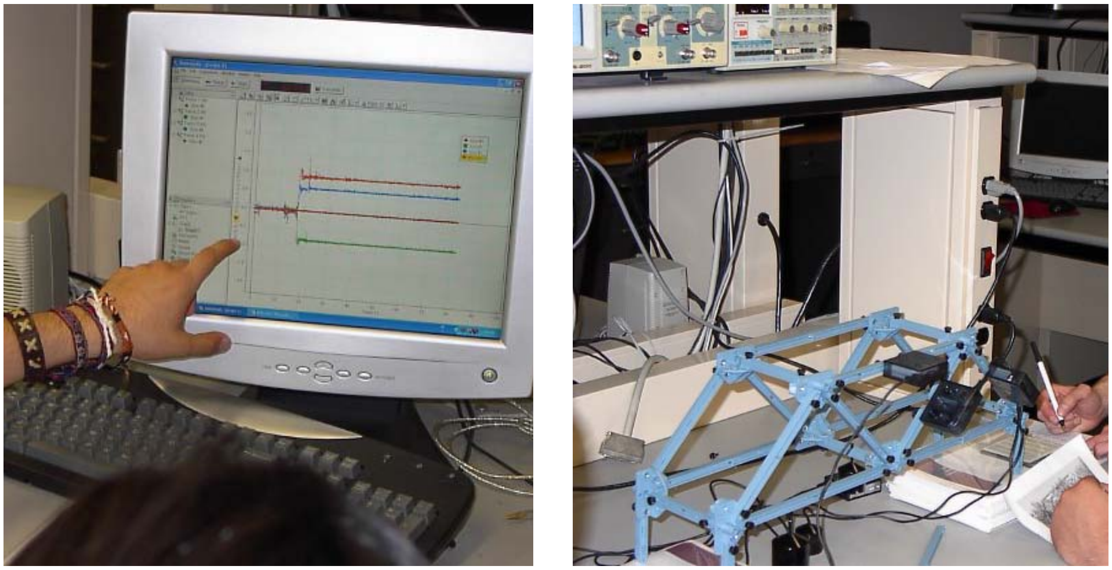
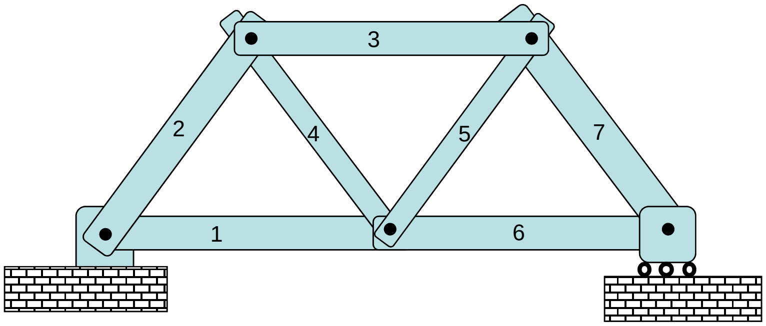


Figure 5. Students Collecting Information in “Test Your Mettle” Step



Type of Load Tension, T / Compression, C	Truss member 1	Truss member 2	Truss member 3	Truss member 4	Truss member 5	Truss member 6	Truss member 7
Truss on Left Side of Bridge							
Truss on Right Side of Bridge							

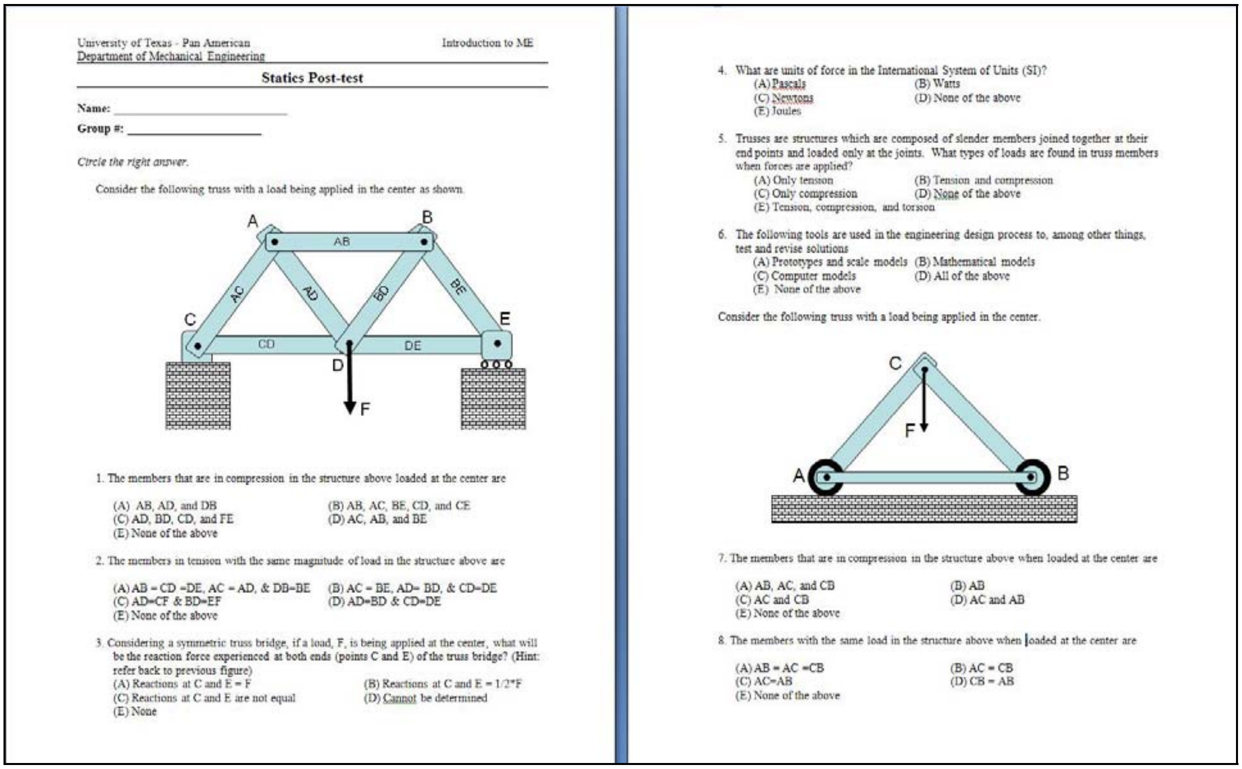
Figure 6. Test your Mettle Handout Figure to Determine Tension and Compression Members

Go Public

As in previous challenges, students must conclude their findings in terms of a presentation to share information with other students.

Assessment Results

The Introduction to ME challenges were implemented in Fall 2009 at UTPA. Through the assistance of the chair, the authors were able to secure two sections of the same course to implement a controlled experiment. The same faculty member taught the two sections with similar class profiles. While one section served as the experimental group, the other section served as a control group. As expected, the authors decided that the experimental group will receive the CBI developed materials. However, it was decided that the control group needed to perform very similar activities to the ones performed by the experimental group but in a more traditional laboratory setup with a significant difference between the contexts of the two treatments. Thus, handouts were created for the control group that did not include the challenge (i.e. real-world context). The handout contained the same reading materials, discussions, and, in addition, a step by step instructions about the creating and testing of the bridge prototypes. Based on the completeness of these handouts, it was easy to think that students in the control group were more likely to perform better than the ones from the experimental group. But we needed to use the assessment instruments to find out the results. As previously mentioned, pre-test/post-test were developed in advance. Figure 7 shows one of the assessment instruments used.



University of Texas - Pan American
Department of Mechanical Engineering
Introduction to ME

Statics Post-test

Name: ______________________
Group #: ________________

Circle the right answer.

Consider the following truss with a load being applied in the center as shown.

1. The members that are in compression in the structure above loaded at the center are

(A) AB, AD, and DB
(B) AB, AC, BE, CD, and CE
(C) AD, BD, CD, and FE
(D) AC, AB, and BE
(E) None of the above

2. The members in tension with the same magnitude of load in the structure above are

(A) AB = CD =DE, AC = AD, & DB=BE
(B) AC = BE, AD= BD, & CD=DE
(C) AD=CF & BD=EF
(D) AD=BD & CD=DE
(E) None of the above

3. Considering a symmetric truss bridge, if a load, F, is being applied at the center, what will be the reaction force experienced at both ends (points C and E) of the truss bridge? (Hint: refer back to previous figure)

(A) Reactions at C and E = F
(B) Reactions at C and E = 1/2*F
(C) Reactions at C and E are not equal
(D) Cannot be determined
(E) None

4. What are units of force in the International System of Units (SI)?

(A) Pascals
(B) Watts
(C) Newtons
(D) None of the above
(E) Joules

5. Trusses are structures which are composed of slender members joined together at their end points and loaded only at the joints. What types of loads are found in truss members when forces are applied?

(A) Only tension
(B) Tension and compression
(C) Only compression
(D) None of the above
(E) Tension, compression, and torsion

6. The following tools are used in the engineering design process to, among other things, test and revise solutions

(A) Prototypes and scale models
(B) Mathematical models
(C) Computer models
(D) All of the above
(E) None of the above

Consider the following truss with a load being applied in the center.

7. The members that are in compression in the structure above when loaded at the center are

(A) AB, AC, and CB
(B) AB
(C) AC and CB
(D) AC and AB
(E) None of the above

8. The members with the same load in the structure above when loaded at the center are

(A) AB = AC =CB
(B) AC = CB
(C) AC=AB
(D) CB = AB
(E) None of the above

Figure 7. Pre-Test / Post-Test Instrument Used in Assessment Efforts

Figures 8 and 9 show the results for the pre-test and post-test for the experimental group (i.e. CBI section – 32 students) and the control group (i.e. laboratory section – 26 students) respectively. Even though the average pre-test scores were higher for the laboratory section (60.6 pts. vs. 54.2 pts.), the post-test scores were higher for the CBI section for more than 2 points (77.6 pts. vs. 75.5pts). While the average gains in correct answers in the CBI section were 23.4 points in each question, in the laboratory section were only14.9 points. Thus, the average gains in correct answers in the CBI section were 57% higher than the laboratory section.

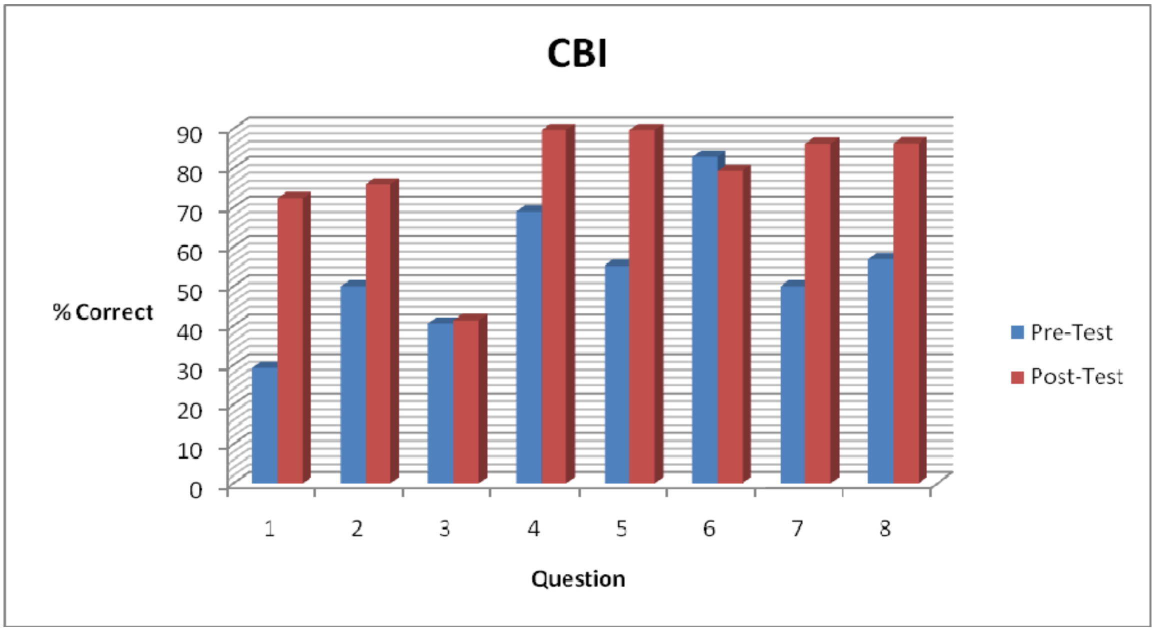


Figure 7. CBI Pre-Test and Post-Test Results for Bridge Failure Challenge (n=32)

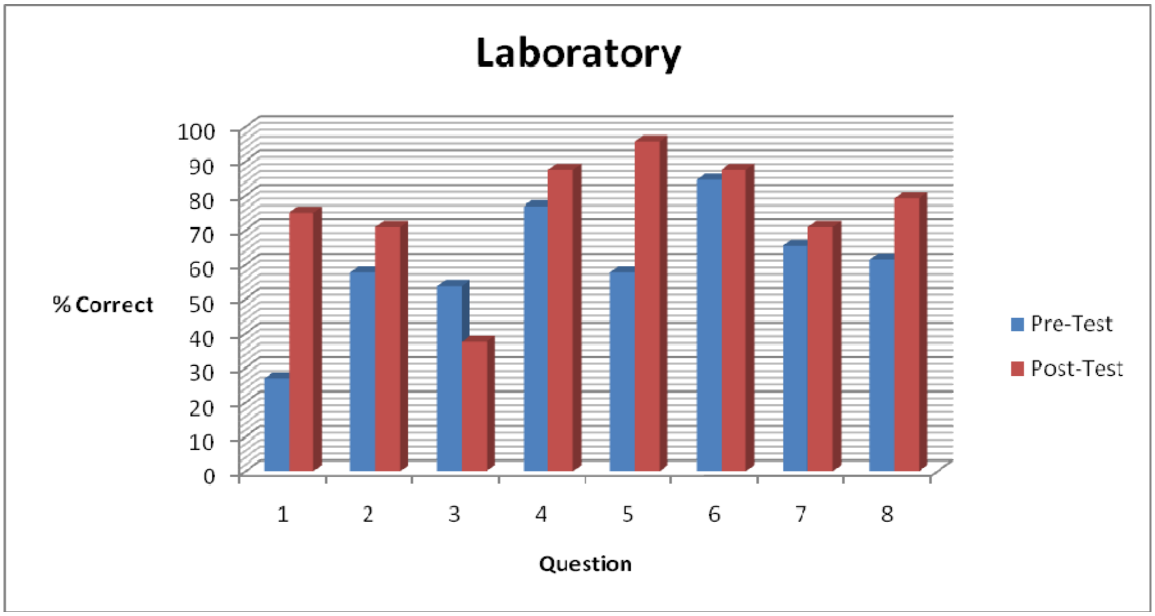


Figure 8. Laboratory Pre-Test and Post-Test Results for Truss Bridge Laboratory (n=26)

The most significant differences between the experimental and the control groups were in questions 7 and 8 designed to test student adaptive expertise. Thus, while the performance of both groups (i.e. CBI and Lab sections) was comparable in most questions, the CBI section significantly outperform the Lab section in the adaptive expertise questions. While the average gains in correct answers in questions 7 and 8 the CBI section were 32.8 points, in the laboratory section were only11.5 points. Thus, the average gains in correct answers in the CBI section in questions 7 & 8 were more than 280% higher than the laboratory section. The results obtained are consistent with results found in the literature including previous assessment results in a different engineering course at UTPA[4].

The experimental group and the control groups displayed similar high level of engagement based on observations by the faculty member as anticipated by the authors based on the literature. This was also evident in the student evaluations since both groups expressed high level of involvement in and satisfaction with the hand-on activities. Both groups also displayed high level of motivation as anticipated from the backward design aimed at motivating learning. Based on these results, it argued that the CBI and lab curriculum developed helped the students to see the relevance of their studies to the real world which is an important factor for student attraction, engagement, and retention. However, the pretest/posttest results provide evidence that students that exposed to CBI developed a better ability to apply the knowledge that they learned in a different context (i.e. adaptive expertise).

Conclusions

This paper describes the CBI curriculum development and its implementation process in a freshman Introduction to Mechanical Engineering course. The CBI instruction was developed and implemented with challenges in the areas of reverse engineering, statics, dynamics, energy (including renewable energy), and forward engineering. An example challenge in the area of engineering mechanics was presented and discussed in this paper. Examples of instructional materials and assessment tools were also presented. Assessment results point to a high level of student achievement and very positive reception of the CBI curricular materials. A controlled experiment was performed with a control group following a more traditional laboratory setup with a significant difference between the contexts of the two treatments. From the initial positive results obtained in this project, it is argued that the VaNTH principles are effective in motivating and engaging freshman engineering students in mechanical and civil engineering majors and in promoting adaptive expertise. The CBI materials and tools developed for the Introduction to Mechanical Engineering course could support other institutions' efforts in student attraction, engagement, and retention.

Acknowledgements

The authors would like to acknowledge the Department of Education, CCRAA-HSI program, for the funding and support to develop and implement this project.

Bibliography

1. Seymour, E., and Hewitt, N.M., “Talking about Leaving: Why Undergraduates Leave the Sciences”, Boulder, CO, Oxford: Westview Press, 1997.
2. Collea, F.P., “Increasing Minorities in Science and Engineering”, Journal of College Science Teaching, 20(1), 31-34, 1990.
3. Freeman, R., Fuentes, A., Vasquez, H., Crown, S., Villalobos, C., Wrinkle, R., Ramirez, O., and Gonzalez, M., “Increasing Student Access, Retention, and Graduation Through an Integrated STEM Pathways Support Initiative for the Rio South Texas Region – Year One Activities and Results”, ASEE Annual Conference, Louisville, Kentucky, 2010.
4. Fuentes, A. A., Crown, S., Freeman, R., Vasquez, H., Villalobos, C., Gonzalez, M., and Ramirez, O., “Increasing Student Access, Retention, and Graduation Through and Integrated STEM Pathways Support Initiative for the Rio South Texas Region”, Proceedings of the 2009 ASEE Annual Conference & Exposition, Austin, Texas, June 14-17, 2009.
5. Prince, M.J., and Felder, R.M., “Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases”, J. Engr. Education, 95(2), 123-138, 2006.
6. Cordray, D., Harris, T., & Klein, S., “A Research Synthesis of the Effectiveness, Replicability, and Generality of the VaNTH Challenge-based Instructional Modules in Bioengineering”, Journal of Engineering Education, 98 (4), pp.335-348, 2009.
7. Altschuld, James W. & White, Jeffry L., “Persistence of Interest in Science, Technology, Engineering, and Mathematics: A minority retention study”, Journal of Women and Minorities in Science and Engineering, 12(1): p. 47-64, 2006.
8. Boaler, J., “Learning from teaching: Exploring the relationship between reform curriculum and equity”, Journal for Research in Mathematics Education, 33(4), 239-258, 2002.
9. Landis, R. “Retention by Design: Achieving Excellence in Minority Engineering Education”, New York, NY: National Action Council for Minorities in Engineering, 1991.
10. Freeman, R., Vazquez, H., Fuentes,. A., Knecht, M., Martin, T., Walker, J., Ortiz, A., “Development and Implementation of Challenge-Based Instruction in Statics and Dynamics, Proceedings of the 2010 ASEE Annual Conference and Exposition.
11. Martin, T, Rivale, S. and Diller, K.R., “Comparison of student learning for challenge based and traditional instruction in Biomedical Engineering. Annals of Biomedical Engineering”, 35(8), 1312-1323, 2007.
12. Schwartz, D. L, S. Brophy, X. Lin, and J.D. Bransford, “Software for Managing Complex Learning: Examples from an Educational Psychology Course,” Educational Technology Research and Development, Vol. 47, No. 2, 1999, pp. 39–60.
13. Prince, M.J., and Felder, R.M., “Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases”, J. Engr. Education, 95(2), 123-138, 2006.
14. Brophy, S., and Bransford, J., “Design Methods for Instructional Modules in Bioengineering”, Proceedings of the 2001 American Society for Engineering Education, 2001.
15. Watai, L. L., Brodersen, A. J., & Brophy, S., “Challenge-based Lab Instruction Improves Interaction in Physical Electronic Circuit Labs”, 2005 ASEE/IEEE Frontiers in Education Conference, October 19-22, 2005, Indianapolis, IN.
16. McTighe, J. and Wiggins, G., “Understanding by Design”, Second Edition. Alexandria, Virginia: Association for Supervision and Curriculum Development, 2005.
17. Vazquez, H., Fuentes, A., Macossay, J., Knecht, M., and Freeman, R., “Development and Implementation of an Introduction to STEM Course for Dual-Enrollment Programs”, Proceedings of the 2010 ASEE Annual Conference and Exposition.