2006-266: DEVELOPING A FUNDAMENTALS OF ENGINEERING (FE) BASED COMPETENCY MODULE FOR A FRESHMAN ENGINEERING COURSE

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Developing a Fundamentals of Engineering (FE) Based Competency Module for a Freshman Engineering Course

Abstract

The tenets of professionalism in engineering practice require that engineers function within their areas of expertise in order to benefit society. The rapid pace of technological change in today's economy challenges this notion of narrow focus by placing a premium on the multi-disciplinary skills of generalists rather than deeper , more narrowly focused skills of the specialists. As engineering students enter a marketplace characterized by rapid technological change, there is a growing need for educators to reconsider approaches to problem solving. New approaches would address preparing today's engineering graduates to solve problems for a broader assortment of products and processes than past generations of engineers. In emerging areas like nanotechnology, the products and processes may involve new principles that engineers learn and apply on their own. This paper reports on a freshman engineering problem-solving module developed to broaden students' perspectives on formulating and constructing their own *student-made problems* as a way to improve problem solving skills and assess knowledge of fundamental principles. The paper discusses students' application of elementary mechanics concepts to solve problems typically found in FE review manuals. The paper also reports on laboratory exercises that help students explore notions of competency by developing their own FE assessment questions from elementary mechanics.

1. Introduction

More often than not, first and second year engineering students see problem solving as merely finding answers to homework problems that lack strong connection to their experiences outside of class. For some students, the frustrations with solving problems for which they do not connect to personal experiences may be enough to cause them to withdraw from the engineering major. Others might develop a disregard for the personal meanings and neglect associations between the assigned problems and the broader concepts discussed in class. For traditional approaches to engineering education, the significance of these early connections are sometimes overlooked because deeper connections are expected to occur later when knowledge of specific facts are blended together within the curriculum to provide the foundation for life-long problem-solving skills[1].

The culminating capstone course is usually the point of synthesis for traditional cognitive theory based approaches to engineering education. These capstone courses are expected to help students broaden their perspectives on how to integrate theoretical and practical knowledge and how to reflect on practice. Within the last decade, employers and leading educators have been complaining that this synthesis, as it pertains to life-long learning and expertise, may not be enough for new graduates to compete in a fast changing global marketplace for engineering services. These leaders suggest that new graduates need: (a) better communications skills; (b) an ability to work in multidisciplinary teams; and, (c) an ability to leverage information technology and modern engineering tools needed to keep pace. The concerns have been reflected in the Accreditation Board of Engineering and Technology's (ABET) revised criterion for engineering and technology programs (EC 2000). In establishing the revised criterion, ABET set a framework for programs to devise strategies for ensuring the skills that graduates should have at graduation and 3-5 years beyond that.

By setting a timeframe on the behavior of graduates, ABET set a challenge for educators to examine the climate for technological change that graduates encounter as they enter the workforce. This look-at-the-pace of technological change raises several important questions. For example, does a climate of rapid technological change impact how we educate engineers? Are approaches to problem-solving that rely solely on synthesis still appropriate when technological change is so rapid that products, processes, and tools may become obsolete overnight? What happens when there are no textbook problems for the principles being investigated? Could approaches based on constructivism be better suited for a climate of rapid technological change?

In drawing contrasts between technological competency in a fast change and a slow change environment, we explored a Fundamentals of Engineering (FE) based competency module for freshmen engineering students at East Carolina University. The goal was to build problem-solving skills based on students' individual processing of how engineering problems are constructed[3-7]. The approach follows a Constructivist view of learning that assumes that the stimuli (problem sets) for adaptive behavior (problem solving skills) should emerge from the leaning environment (classroom interactions) and not from the stimuli themselves (textbook problems). In this sense, Constructivism suggests that the information that informs competence and skill resides within the constructs developed by the learner rather than within the external environment (textbooks or classrooms) from which it is drawn.

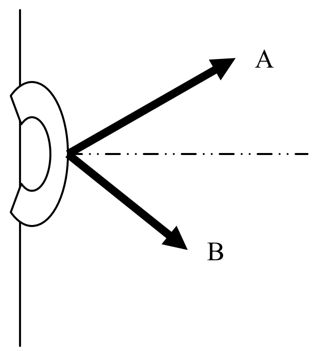
2. Method

Thirty-six freshmen students in an introductory engineering course were presented six hours of lecture on elementary mechanics topics and assigned problem sets that were graded by the instructor. The problem sets were assigned to assess how well students: (a) applied the Laws of Sines and Cosines; (b) constructed force triangles for adding vectors; and, (c) resolved forces into rectangular components for summing forces and moments for the equilibrium condition ($\sum F = 0$ and $\sum M = 0$). The frequency of errors were recorded before and after groups of students were asked to construct their own problems for assessing the competency their peers. Errors were cataloged as indicated in Table 1.

1a	computation with the law of sines
1b	computation with the law of consines
2a	signs while resolving forces into components
2b	signs while computing moments computations
3a	ignored contribution while summing forces
3b	ignored contribution while summing moments

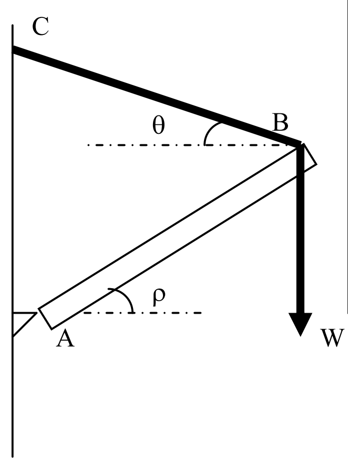
Table 1. Common problem-solving errors for elementary mechanics

In developing *student-made* FE Competency problems, students were asked to follow a standard instructor template that reflected learning outcomes. Two illustrative examples of instructor templates are shown below.



Two vectors form a concurrent force system and Vector A is *a* Units and acts at φ degrees. Vector B is *b* Units and acts at ρ degrees. Determine the resultant.
Note: 0≤ρ360

Figure 1. Concurrent Force System Framework Problem



The beam AB of length L, hinged at A and supported by cable BC, is subjected to force W. Determine the reactions at A and the tension in the cable. Neglect the weight of the beam.

Note: θ+ρ =90

Figure 2. Equilibrium Framework Problem

The common problem-solving errors cited in Table 1 are consistent with earlier work by Steif [2,8] who proposed four clusters of Statics concepts required for mastery of the subject. The current investigation only addresses the cluster involving summation of external forces on a body in equilibrium. While an approach using *student made* problems could be used to assess students' inventory of concepts, this is not the primary purpose of our study. The purpose of the investigation is to explore the pedagogical implications and applications of constructivism for engineering problem solving. In this sense, the goal is to explore how students' construct and reconstruct their conceptions of phenomena[9] as they become more skilled problem-solvers. Since students interpret new information on the basis of their existing knowledge and past experiences, developing problem-solving skills using constructivist strategies requires emphasis on the social interactions and collaborations that help students attribute appropriate meanings to problem-solving activities. As such, the strategy is to involve groups of students in the cyclic process of formulating and solving problems and using group efficacy[9] effects for students to assess the different approaches followed by their peers involved in the same problem-solving process.

3. Results and Discussion

Students were placed in nine randomly selected groups for problem solving activities before and after the groups exchanged problems they developed themselves. Each problem solving session lasted 20 minutes for a five problem set. The frequencies of common errors (1a – 3b) for the nine groups (4 students per group) are shown below in Table 2.

Error Code	Description	Before Framework Problems	After Framework Problems
1a	computations with the law of sines	4	1
1b	computations with the law of cosines	6	2
2a	signs while resolving forces into components	7	2
2b	signs while computing moments	3	4
3a	ignored contribution while summing forces	5	3
3b	ignored contribution while summing moments	8	5

Table 2. Frequency of common problem-solving errors for elementary mechanics

The frequency of common errors decreased for all except error 2b; therefore the results appear to confirm expectations that as students spend more time creatively constructing their own problems, their problem-solving skills improve. Since it is also true that the extra time is the controlling factor for the change, we also explored the improvements in terms of students' self efficacy beliefs.[9-10] Bandura[11] defines this self-efficacy as students' perception of their capability to accomplish a desired task. Moreover, self-efficacy is important since it influences the course of action students choose to pursue in their efforts to build problem-solving skills— how long they persevere in facing obstacles and their resilience to setbacks. In this sense, *student-made* problems appear to help students better adopt learning objectives as personal goals, regardless of their personal starting point. By defining problems at their initial level of competence, students were better able to set proximal sub-goals within their range of self-efficacy. *Student-made* problems as *mastery experiences* may also strengthen self-efficacy beliefs since the goals for problem solving activities are much clearer for students. If students are unable to define clear goals for problem-solving tasks, the haziness of the goal provides little cognitive feedback on how well their performance is leading to the goal. In this sense, they have little motivation to attempt homework problems they perceive beyond their capability. We saw that once students started constructing their own problems, they automatically set goals that involve problems with higher levels of challenge. This instinct to raise the level of challenge arises from motivation to close the discrepancy between the skill level they perceive they have and the next higher level. More challenging problems create greater discrepancies and consequently greater motivation due to the anticipated self-satisfaction if the challenge is met. We are planning to explore these connections in follow-on work aimed at assessing whether students' self-efficacy beliefs about course objectives are different if *student made* problems are used exclusively instead of traditional textbook problems.

An observation of student groups engaged in problem-solving in this way can provide instructors with valuable insight into the learning goals students set for themselves since their learning goals are often reflected in the types of problems they formulate. In this way, *student made* problems provide a strategy for organizing learning on the basis of interactive and cooperative forms of problem-solving where students reflect on their individual interpretations and understandings of the theories and principles involved in problem-solving tasks. This also creates opportunities for instructors to assess the types of qualitative changes that are occurring in students' knowledge. During the in-class problem-solving lab, these qualitative changes were reflected by the increases in the number of interrelated concepts that students were able to incorporate into each problem. Besides creative applications of geometry, these interrelated concepts involved going beyond a balance of forces to incorporating moments in the equations of equilibrium. To keep problems within the scope of the FE course module, students were asked to designate problems as either simple or complex. Complex problems involved three or more interrelated concepts tied to learning objectives while simple problems involved two or fewer interrelated concepts. Designating problems into these categories helped students set personal definitions for competency and provided peer measures for proficiency in solving both types of problems.

4. Conclusions:

This paper has presented a Constructivist perspective on helping students develop problem-solving skills by engaging them in the process of formulating their own problems using generic frameworks. The results were encouraging since the frequency of common errors decreased for elementary mechanics topics. Additionally, the strategy engaged students in the process of formulating problems as a means to assess competency for themselves and their peers.

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