Work in Progress - A Statics Skills Inventory

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Abstract - This paper focuses on assessment of student skills in statics and provides details of development of a statics skills assessment tool. The use of only concept inventories to provide proof of student learning is an incomplete assessment as important engineering knowledge consists of both conceptual knowledge and skill intertwined. A multi-step Delphi process involving a group of engineering educators was used to reach consensus on the important skills of statics. These skills are currently grouped into 10 categories. The Delphi rankings included both the average importance of the skill as judged by the Delphi participants and their judgment of the average proportion of their students whom can perform the skill. Skill-based questions are being developed to probe these areas.

Index Terms – assessment, Delphi process, engineering mechanics, skills, statics.

INTRODUCTION

Statics is the first in a series of courses within the broader subject area commonly referred to as engineering mechanics. Virtually all engineering and engineering technology students take statics and it is a fundamental course prerequisite for other important mechanics courses like dynamics and strength of materials. Success in these latter courses is directly correlated to success in statics [1].

Demonstrated proof of student learning and mastery of engineering knowledge is now required by the Accreditation Board of Engineering and Technology’s (ABET) outcomes-based environment [2]. This has led to the need for tools for assessment of individual student learning. Additionally, engineering faculty need instruments for formative use in assessing implementation of new course design strategies and instructional practices intended to increase student learning. Following the lead of the physics community, the bulk of development effort for these purposes has focused on concept inventories. Typically, these concept inventories focus on determining student understanding of a subject’s fundamental concepts, usually through questions involving minimal calculation. An example is the recently fielded concept inventory for dynamics, a tool complementing the previously developed Force Concept Inventory [3, 4].

The use of only concept inventories to provide proof of student learning can be argued to be an incomplete assessment as important engineering knowledge consists of both conceptual knowledge and skill intertwined. For instance, while demonstrating understanding of the concept of equilibrium is valuable, it is also important to be able to generate correct independent equations of equilibrium.

Thus, this paper focuses on assessment of student skills in statics and provides details of the development work towards a statics skills assessment tool.

DEVELOPMENT PROCESS

A multi-step Delphi process involving a group of engineering educators was used to reach consensus on the important skills of statics. Don Evans, Emeritus Professor at Arizona State University, provided insight into the Delphi process and how it had been conducted for other concept inventory development efforts. Participants were recruited from a mechanics listserve as well as by personal recommendation from the project team. The first round of the Delphi process asked participants to contribute their personal list of important statics’ concepts and skills. The original responses from the first Delphi round included 101 items listed as concepts by the contributor and 24 separate items listed as skills. A condensation process then resulted in lists of 32 concept items and 43 skill items.

After analysis, these 43 skills were further subdivided and expanded into a list of 53 skills. This process allowed the skill list to clearly delineate the task. For instance, calculating the area moment of inertia appears twice, once by the composite method and once by integration. This expanded list was then the subject of a second round of the Delphi process. Experienced engineering mechanics’ educators were asked to rank both the average importance of the skill as judged by the Delphi participants and their judgment of the average proportion of their students whom can perform the skill (essentially a ranking of the student mastery of the skill).

The 53 skills were grouped into 10 basic categories. These were:

- algebra and geometry skills (a list of three skills),
- properties of areas and volumes (a list of eight skills),
- vector manipulation skills (a list of seven skills),
- modeling and free body diagrams (a list of eight skills),
- equilibrium equations (a list of five skills),
- manipulation of forces and force systems (a list of nine skills),
- manipulative and force skills (a list of ten skills),
- kinematics (a list of five skills),
- forces (a list of three skills),
- moment of inertia (a list of three skills).
• trusses (a list of four skills),
• frames and machines (a list of three skills),
• friction (a list of four skills), and,
• general (a list of two skills).

The results from the second round of the Delphi process were analyzed. Participant ratings of importance and student mastery provided a primary and secondary ranking system of skill importance. The importance of the skill was the primary ranking method. Then, within the importance rankings, the student mastery data provided a way to rank skills within a similar importance ranking (for instance, there were six skills with an average importance ranking of 9.5). The average student mastery ranking of the skill was used to create a difference of the importance score minus the student mastery score. This result, for each skill, was used as the secondary ranking data and provided a way to distinguish between important skills that students typically master as compared to important skills where students may not typically obtain the desired level of proficiency. This approach provides a mechanism where the team can eliminate an important skill from the test simply because most students obtain mastery of the skill in the typical statics class. It is possible that questions probing these skill areas may be impacted by a ceiling effect, thus limiting their value as a discriminator of student statics skill mastery. Since a skills (or concept) inventory necessarily will be limited in the number of questions, these data provide developers a tool to help decide which skills will, or will not, be probed.

Currently the team is considering the top ranked 38 skills (by importance). Within this set, there are 10 skills with an importance minus mastery score of less than 0.7 (overall scores ranged from 2.4 to 0). We expect that, based on the distribution of these skills within the broader categories, some of these low scoring skills will be dropped from skills inventory.

While space prevents a complete listing of the 38 high-ranking skills, it is interesting to note the distribution of the top 12 ranked skills (by importance rankings) within the broader skill categories. These are:
• algebra and geometry skills (one of top 12 skills),
• vector manipulation skills (three of top 12 skills),
• modeling and free body diagrams (two of top 12 skills),
• equilibrium equations (four of top 12 skills), and,
• manipulation of forces and force systems (two of top 12 skills).

Skill-based questions are being developed to probe the top ranked skills (where the importance minus mastery score is greater than 1.0) even as the group works towards consensus on which of the 38 skills to remove. Unlike concept inventory questions, these skill assessment questions will require calculation and use of formulas. The initial development thrust for these questions will focus on questions that are less complicated than typical statics homework or exam problems. In these more typical problems, multiple skills are required to solve the problem. In a skills inventory, such a problem could cloud the instrument’s ability to assess student mastery of specific skills as well as impact the time necessary for completing the test.

Once an alpha version of the statics skills inventory is completed, it will be used in a limited number of statics classes. Student focus groups also will be used as well to help identify problem issues. After this initial feedback is incorporated into the instrument, broader field-testing will begin.

CONCLUSIONS

While statics concept inventories may be useful tools for engineering educators, a statics skill inventory is also of value. Development of such a tool is underway and the work done to date includes a Delphi process with experienced engineering mechanics educators to establish the important skills within statics. Questions are being developed to probe these skills. Developing a statics skill assessment tool recognizes the importance of skills, both student obtainment and subsequent measurement of that attainment, to engineering education. Such a tool will complement assessment via statics concept inventories.

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REFERENCES


