



Toward a Multi-Dimensional Taxonomy for Statics Problem Classification and Problem-Solving

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Work in Progress: Toward a Multi-Dimensional Taxonomy for Statics Problem Classification and Problem-Solving

Abstract

This work builds upon prior work in developing robust concept inventories and skill assessments for statics instruction. While these instruments provide valuable tools that allow instructors to assess student progress, there is still need for learning materials to scaffold student learning from disconnected procedural and conceptual knowledge, to more holistic metacognitive knowledge. This work-in-progress presents a multi-dimensional taxonomy generated by the author to scaffold problem-solving in an introductory statics course. The taxonomy was built from problem classifications identified in well-established concept inventories and skill assessments for statics, literature around difficult problems in statics, and personal experience and observations from teaching the subject over several years. The purpose of the taxonomy is to encourage students to think about characteristics of the system, characteristics of the problem, and specific known and unknown components within the system before they begin to work on an appropriate solution.

Introduction

Engineering practice relies on the successful utilization of conceptual knowledge with regard to system design, problem-solving processes, and developing professional competence in the field [1]. The objective of instruction is to bring about conceptual change that will lead to the development and cultivation of expertise [2], where procedural skills and conceptual knowledge are contextualized and well-connected. Experts can quickly process new information and categorize what is and is not important to solve a given problem or accomplish a given task within their expertise. Rittle-Johnson and Siegler suggest that problem-solving is improved through cyclic, iterative development of conceptual and procedural knowledge [3]. In learning introductory mechanics, however, many students tend to build strong procedural skills, without the accompanying conceptual knowledge to support it [4]. Litzinger et al. [5] studied problem-solving strategies of both weak and strong statics students and found that even among strong problem-solvers, students relied heavily on memorization of equations and algorithms to reason through problems, rather than conceptual understanding of the physical system. They did, however, find that the strong problem-solvers could be recognized by their use of metacognitive control processes (e.g., self-explanation). Similarly, Steif et al. [6] questioned if explicit focus on bodies during instruction would improve problem-solving performance, and found that students benefitted from “instruction that promotes a more systematic discussion of bodies and that the use of metacognitive prompts may help students develop a body-centered representation and help them monitor their problem solving process.”

The impetus for this study was to better scaffold conceptual understanding through explicit classification of systems and problems, to develop vocabulary, problem representation, and stronger connections between conceptual understanding and procedural skills.

Taxonomy Development

The objective for developing the *Taxonomy of Problem-solving in Statics* (TOPS) was primarily to uncover hidden decisions an expert might make in deciding how to approach a statics problem. The flow-chart design was used intentionally to facilitate classroom instruction and discussion. The classifications were drawn from the content and organization of several major textbooks (e.g., [7], [8], [9]), delineations between subsets of problems in the Concept Assessment for Test for Statics [10], as well as personal observations from my own teaching. An example of one section of the TOPS classification system, used for particle mechanics systems, is shown in Figure 1.

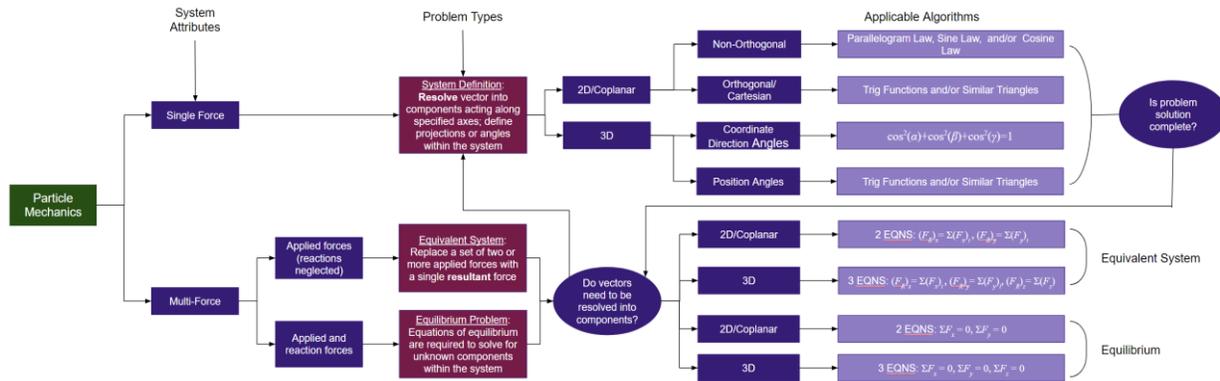


Figure 1. TOPS Classification Flow Chart for Particle Mechanics Problems

The TOPS is organized into two primary dimensions: system classification and problem classification. The system classification prompts students to make key observations about the system or subsystem, such as dimensionality (coplanar vs. 3D), whether the forces are symmetrical about an axis, whether forces are concurrent or parallel, etc. The problem classification has three main categories of problems: equivalent system, equilibrium, and system definition. The objective of an equivalent system problem is to replace a “complex” (meaning two or more) loading system and simplify it to a less complex (e.g., either a single force, or a force and couple moment) loading system with an equivalent net effect. The equilibrium problems will use equilibrium equations, either with or without friction equations, to solve for system unknowns. The system definition classification is more of a miscellaneous category for problems that require a specific element or attribute be defined. Where equilibrium problems generally aim to solve a physical problem (e.g., what does the mass of a given block need to be to hold a system in equilibrium), system definition problems aim to specify only one or two attributes within the system (e.g., resolve a force into its rectangular components, define an angle between two vectors, define the moment of force at an assumed point of rotation, etc.). In most cases the system definition problems will later become an embedded step in more complex problems.

When organized as a flow chart, identifying the system classification and problem classification can visually be observed as an iterative process, where the problem classification is both influenced by and influences elements of system classification. Combinations of system and problem classifications are matched with generalized “base” algorithms, which would then need to be manipulated to serve the specific needs of the problem.

Work In Progress: Research Objectives and Methods

The goals of the work in progress are guided by the following questions:

1. Does following the TOPS classification flow chart increase problem-solving accuracy among mid and low performing students enrolled in a first-year statics course?
2. Does following the TOPS classification flow chart increase problem-solving accuracy among second or third-year students enrolled in advanced mechanics courses?

The TOPS classification system being developed for use in a two-part study with a quasi-experimental design. In the first phase of the study, participants who are currently enrolled in statics will be randomly assigned to two groups. The students in the first group will be given a set of problem statements, similar to typical textbook problems, without any additional information. Students in the second group will receive the same problem set, and the TOPS classification flow chart. The second phase of the study will use the same prompts with students in the sophomore and junior year who have taken statics one or two years ago.

In this future work, the author expects to see some evidence that using the TOPS as a scaffolding tool will help give students, particularly those in mid- and low-performing groups, guidance in how to select appropriate algorithms for solving statics problems, and thus improve their overall performance. The author also supposes that regular use of taxonomic language throughout the full duration of the statics course will help with long-term retention of conceptual understanding to support procedural approaches to problems.

The objective of the current work-in-progress is to present the early stages of development of the TOPS to a community of educators and researchers that can provide valuable feedback prior to the tool being applied in the first phase of the aforementioned research design.

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