INVESTIGATING TRAJECTORIES OF LEARNING & TRANSFER OF PROBLEM SOLVING EXPERTISE FROM MATHEMATICS TO PHYSICS TO ENGINEERING

Project Summary

This *Empirical Research* proposal submitted to the *Measurement, Modeling and Methods* category of the *Frontiers Research* strand presents the case for a project that investigates how science and engineering students build toward problem solving expertise through a major part of the academic careers and how they transfer their knowledge and skills across undergraduate STEM courses while building that expertise.

Most professional scientists build problem solving expertise through years of undergraduate STEM courses by starting with relatively simple and structured problems in introductory courses and progressing to more complex and unstructured problems in upper-division courses. These academic experiences help prepare them to become creative problem solvers in their future professional life. While problem solving and the mediating factors have been studied in various formal and informal learning contexts, the process of development and change in the level of problem solving expertise over the duration of a scientist's or engineer's undergraduate experience has not been carefully studied. Further, research has not yet investigated how problem solving skills transfer through a series of STEM courses to provide a set of coherent experiences that helps develop the students' overall problem solving expertise. Thus, we do not yet know what can be done to optimize the learning trajectory toward problem solving expertise by preparing research-based coherent experiences across several courses.

Our project is a step in creating a knowledge base on the evolution of students' problem solving skills over the span of three years of STEM courses. We investigate the development and transfer of problem solving skills in undergraduate mathematics, physics and engineering courses. First we use individual semi-structured interviews to capture fine grained data about individual student's problem solving. Based on these insights we enhance an adaptive online system to collect data from large numbers of students and map students' learning trajectories as they build toward problem solving expertise. In each phase, we conduct longitudinal as well as cross-sectional studies in multiple courses in mathematics, physics and engineering. Over three years we will investigate problem solving by over 3000 students in seven different courses in mathematics, physics and engineering.

Intellectual Merit

This project will lead to models of the development of student problem solving skills as they progress from calculus through introductory physics to engineering courses. Models of change in students' problem solving abilities will provide a new and unique look at how their problem solving knowledge and skills progress and develop over a series of courses. This knowledge base will contribute significantly to increasing our knowledge of the way in which students' understanding and skill builds through their undergraduate academic careers.

Broader Impact

The project articulates a framework for research on problem solving and transfer that can be applied to other content domains. The online system developed by this project serves as an exemplar and precursor for more sophisticated technology-based systems that serve both as excellent educational as well as research tools that provide new insights into how students develop and transfer expertise in problem solving.

The results of this study can provide a road map to faculty in a variety of STEM disciplines on ways to create and coordinate the development of problem solving skills across several years of an undergraduate education. Thus, the application of this research to curriculum development will be a series of courses in which faculty help students transfer their problem solving learning and build toward expertise much more innovatively and efficiently than they do now.