

***Thinking in Physics* Project Summary**

Rising Above the Gathering Storm, a study commissioned by the National Academies of Science, recently identified the critical importance of increasing the number of graduates in science, engineering, and mathematics in the U.S. Up to half of those who enter college as STEM majors switch to other disciplines. In an effort to make their courses more engaging, STEM instructors often create inquiry based activities. Yet even in such interactive classes, students with limited reasoning skills and unfavorable attitudes and beliefs about learning are unable to thrive, as demonstrated by the research of the PI and the Co-PI. *Thinking in Physics* aims to provide additional help for these students, improving their reasoning skills and their views about learning, providing the foundation for successful careers in STEM.

This project's primary objectives are to: 1) create instructional materials and methods that will be used to develop students' reasoning skills; 2) improve students' post instruction performance on measures of reasoning ability, beliefs about learning, and conceptual understanding in physics; 3) improve retention rates and grade point averages of STEM students.

Philip Adey developed the Cognitive Acceleration through Science Education (CASE) program, funded by the British Economic and Social Research Council. He used science to teach middle school children to think. Participants achieved dramatic, long term learning gains in areas of science, mathematics, and even English. Israeli psychologist Reuven Feuerstein developed a successful intervention designed to help children with low IQ's. Karplus and Kurtz developed the Numerical Relationships (NR) program and dramatically improved proportional reasoning skills of high school students who had not responded to traditional instruction.

In this project the PI and Co-PI will develop instructional material and methods appropriate for college students, inspired by the CASE, Feuerstein's Instrumental Enrichment (FIE), and NR programs. Professor Adey has agreed to allow the PI and Co-PI to adapt CASE materials for use by American college students. A small pilot study employing these methods has already shown success. The PI and Co-PI will provide instruction to selected Loyola Marymount University (LMU) STEM students. LMU is a private, Catholic university, with an undergraduate enrollment of 5,465, with a diverse student body, including many from groups that are underrepresented in the STEM workforce: 60% of the College's students are women, and 31% identify themselves as Hispanic or African American. Classes will meet in LMU's Interactive Physics Classroom, which provides an ideal setting for the project's group work.

Intellectual Merit: Both understanding of basic concepts in physics and strong scientific reasoning ability are essential for science and engineering majors. This project will provide the means to satisfy these critical needs in an original, creative way. The PI and Co-PI have extensive knowledge of cognitive development, how to assess it, and its connection to conceptual understanding in physics. One of the external consultants, Edward Redish, is a distinguished authority in physics education research and cognitive development. The other, Philip Adey, is a distinguished British expert, the originator of the CASE program. The project itself is a creative, original blend of research-based pedagogy and assessment, using highly effective assessment methods recently developed by the PI and Co-PI.

Broader Impact: The impact of this project will be broadly felt through local workshops for college instructors, presentations at national conferences, publications in peer-reviewed journals, and distribution of web-based materials. The project offers a great potential benefit to society by helping to make careers in science and engineering possible for many students, including members of underrepresented groups, who might otherwise find college-level science courses impossible.