What Works in Undergraduate Physics Education?
A Research Synthesis
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Introduction
The Physics Education Research (PER) community has challenged the traditional model of undergraduate physics in recent decades, questioning the value of a single professor lecturing to large classes of students. In an attempt to improve upon the traditional model, the PER community has taken steps to better engage students and help them take a more active role in their own learning. The National Science Foundation has provided support for these course innovations and, as a result, an immense amount of empirical research has accumulated on the effectiveness of these innovations. Despite the explosion of research studies on undergraduate physics course innovations, no systematic attempts have been made to identify which instructional innovations are most effective in helping students learn, and the possible reasons why some of these innovations are more effective than others. Although there have been several published quantitative summaries of the innovations, these approaches have either focused on synthesizing the effect of a single innovation over a period of time (Beichner, Saul, Abbott, Morse, Deardorff, Allain, Bonham, Dancy, and Risley, 2007; Crouch, Watkins, Fagen, & Mazur, 2007; Crouch & Mazur, 2001; Fagen, Crouch, & Mazur, 2002), or have grouped many conceptually different innovations into one broad category (Hake, 1998) rather than comparing different innovations with each other.

Clearly, the PER community needs a more thorough synthesis of what innovations have been developed, which ones have been effective, and why they have been effective in order to inform future directions undergraduate physics education. Heidi Iverson, a 5th-year doctoral candidate in the School of Education, is working on just such a synthesis for her doctoral thesis. This research began as part of an NSF-funded research project to quantitatively synthesize the research on undergraduate instructional innovations in multiple disciplines. However, Heidi intends to go beyond the original scope of the NSF study to qualitatively analyze the most effective innovations in physics to and identify which aspects of the instructional approaches are most effective at improving the quality of undergraduate physics education. Furthermore, Heidi wants to bring the educational research literature to bear on these innovations to determine why certain approaches are more effective than others for the purpose of mutually informing future innovation development in K12 science education and the PER community.

Heidi’s thesis will respond to the following questions:
(1) What are the different kinds of innovations in undergraduate physics teaching?
(2) What are the effects of these course innovations on student learning?
(3) Why might certain innovations be more effective than others?

Heidi’s project will integrate research in Physics education with the knowledge base in K-12 science education, furthering iSTEM’s goal in establishing the University of Colorado as a hub of STEM education. In addition her research innovatively combines qualitative and quantitative
research approaches to help answer the burning question: *What works in undergraduate physics instruction?*

**Proposed Method**

Heidi’s research represents a significant extension of the original research goals of the UCI project and will employ both quantitative and qualitative methods of analysis. Through meta-analysis, Heidi will determine the relative effectiveness of different innovations. The results of this analysis will then inform a case-study analysis in which Heidi will determine the common features of effective innovations.

In education, meta-analyses quantitatively synthesize the results of empirical research studies. (Lipsey & Wilson, 2001). In her meta-analysis, Heidi will synthesize and combine the research by grouping studies in a variety of ways, including the type of innovation (e.g., University of Washington tutorials, Studio Physics, etc.) and research design used (e.g. pre-post control group, posttest only, etc.). She will then calculate mean effect sizes within groups in order to make comparisons of effectiveness across innovation type. This part of Heidi’s dissertation is currently in progress and will be completed by the fall of 2010, clearing the way for the qualitative analyses that she has proposed.

The significant portion of Heidi’s work to be completed during the 2010-2011 school year is as a case study investigation into the most effective innovations to qualitatively unpack ‘what works’ (Merriam, 1998; Yin, 1984). Heidi will draw upon her extensive knowledge of science education to look for patterns in the most effective innovations and relate them to the knowledge base in the K-12 educational research community. The purpose of the case studies will be to create hypotheses about why certain innovations are more effective than others. In this analysis Heidi will identify the common components of these innovations; for example, the degree to which students are posing their own questions or making connections to their own prior knowledge, or the extent to which instructors collect information about student thinking and tailor their teaching accordingly. In this part of her work, Heidi will analyze curriculum documents, instructor guides, and student materials, as well as conduct interviews with innovation developers for the purpose of identifying the components that are common to the most effective innovations. The case studies go beyond what one usually sees in a meta-analysis to suggest not only which innovations themselves are more effective, but also to gather data that will help her to determine why certain innovations may be more effective than others.

The funding requested from iSTEM will support Heidi for a 25% assistantship for the 2010-2011 academic year when she will complete her proposed analyses, draft and defend her thesis. During this time she will also and begin to draft manuscripts and proposals for scholarly journals and conferences to disseminate her findings to both the PER and educational research communities.
Contribution to the Field
The contribution of Heidi’s dissertation is three-fold: she will (1) provide a roadmap of what’s been done in undergraduate physics innovation, (2) evaluate the relative effectiveness of these innovations, and (3) provide some insight into why certain innovations are more effective than others. These findings have the potential to move the conversation in undergraduate physics reform beyond individual innovations toward a conversation about different teaching and learning activities that help students learn. In this way, Heidi’s research will inform the next generation of physics innovations by suggesting guidelines to inform future reforms in undergraduate physics instruction. Furthermore, Heidi’s research will facilitate and supplement collaborations between the PER community and schools of education: a central tenet of the iSTEM initiative.

Departmental Funding and Support
Although Heidi’s dissertation research is not currently supported by any funds in the School of Education, she was previously the recipient of funding from the UCI Project from the summer of 2007 until the grant ended in 2009. It was from this funded research project that Heidi’s dissertation topic grew, and now her research is continuing on this topic even after the funding has ended. Thus our department views a 25% match as having occurred in previous semesters, and hopes that iSTEM funding can make possible the completion of this important, synergistic research. There is no current or pending funding for Heidi’s project outside this proposal to iSTEM.

While no financial support is available for Heidi’s research, Heidi has the full support of mentors in the school of education for completion of her project, including her advisor, Professor Erin Furtak, as well as the co-PI’s on the UCI grant: Dean Lorrie Shepard, Professors Derek Briggs and Valerie Otero, as well as Professor Maria Araceli Ruiz-Primo from the University of Colorado Denver.

Relation of Proposed Work to Degree Plan
As described above, the proposed research will be Heidi’s doctoral thesis. She successfully defended her dissertation proposal in the summer of 2009. Thus, the proposed work is integral to the completion of her degree program in the School of Education.

Timeline
Heidi has set forth a reasonable work plan that builds upon the work she has already completed and plans to complete over the summer. The table on the following pages breaks down the different research activities she will conduct during the 2010-2011 academic year, putting her on schedule to finish and defend her thesis in spring 2011.
### Analytic Method: Tasks & Sub-Tasks

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<th>Range of Working Dates &amp; Proposed Date of Completion</th>
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<td><strong>Analytic Method: Tasks &amp; Sub-Tasks</strong></td>
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<td>Perform meta-analysis</td>
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### References


