Enabling Informed Adaptation of Reformed Instructional Materials

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Abstract. Instructors inevitably need to adapt even the best reform materials to suit their local circumstances. We offer a package of research-based, open-source, epistemologically-focused mechanics tutorials, along with the detailed information instructors need to make effective modifications and offer professional development to teaching assistants. In particular, our tutorials are hyperlinked to instructor's guides that include the rationale behind the various questions, advice from experienced instructors, and video clips of students working on the materials. Our materials thus facilitate their own implementation and develop instructor expertise with PER-based instructional materials.

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MOTIVATION

Instructors who adapt reformed instructional materials to suit their local circumstances may be institutional constraints, inflexible limited by materials, or their own lack of expertise. Nonetheless, they make adaptations. In order to assist instructors in making informed modifications and implementing materials effectively, we offer a package of opensource physics worksheets integrated with implementation resources. In what follows we describe the resource package and three different ways instructors have used these materials.

OPEN-SOURCE MATERIALS INTEGRATED WITH IMPLEMENTATION RESOURCES

The package that we provide includes a sequence of tutorial and interactive lecture worksheets, homework and solutions, an instructor's guide, video of students working on the tutorials, and commentary and discussion questions to accompany the video.

Tutorials and Interactive Lecture Worksheets

A *tutorial* is an active-learning worksheet intended for use by small groups of students, optimally 3 or 4 students per group, in a small-class setting (typically 20 students or so). If experiments are involved, students usually work on them within their small groups. The instructor or instructors float around interacting with individual groups. The tutorial worksheets are typically not graded; instead, students get feedback from TAs during the tutorial sessions, and on homework and quizzes. We find that grading the tutorial worksheets tends to result in students giving the answers they think we want to hear, rather than saying what they really think.

An *interactive lecture demonstration* (ILD) is much the same, except it is intended for use in large lectures. Students work with whomever they happen to be sitting. Instead of interacting with individual groups, the instructor leads a full-class discussion at designated points in the worksheet. Any relevant experiments are set up at the front of the class. As with tutorials (and for the same reasons), we do not typically grade ILD worksheets.

The tutorials and interactive lecture worksheets that we offer are developed by the Physics Education Research Group at the University of Maryland (UM) for the algebra-based introductory physics course, based on the model developed at the University of Washington (UW).¹ The materials cover core concepts in 1st-semester introductory physics (kinematics, forces, momentum, energy, and hydrostatic pressure). UM tutorials and ILDs are developed to promote students' epistemological development along with their conceptual understanding, as part of our response to research indicating that even the best reform materials don't typically improve students' views about the nature of physics knowledge and learning.²

With each tutorial, we provide homework questions that reinforce and in some cases build upon the tutorial. Like the UW tutorial developers, we find that to maximize the effects of tutorials and ILDs, it is essential to use at least some associated homework items. Similarly, we find it is important to use some of the included exam questions, which are designed to reward students for gaining the kind of conceptual understanding that the tutorials emphasize.

All the text materials that we provide are fully editable Microsoft Word documents. Instructors can easily make any changes desired with no restriction. They may add or delete material, change wording, divide worksheets into smaller segments, or change the form of the worksheet (perhaps turning a tutorial into an interactive lecture, or even homework).

Each tutorial and interactive lecture worksheet is hyperlinked in multiple places to an instructor's guide containing an overview of the worksheet and the rationale behind it, in addition to section-by-section discussions of common student responses, teaching tips, and so on (see below).

Instructor's Guide

The instructor's guide includes information that we would hope would be helpful for someone implementing the tutorials without other expert assistance. In addition to detailing the necessary equipment and the flow of the lesson, we provide an overview of the purpose and method of the lesson; the curriculum developers' reasons for writing the lesson in a particular way; and references to the physics education literature relevant to the lesson topic. For specific questions within the worksheet, we also relate common student responses; expert instructors' experiences in helping students make progress; and questions for instructors to ask students at particular points in the lesson. Our goal is for the text of the instructor's guide to contain information similar to what we would tell a new tutorial instructor at our own institution.

In addition to the text, the instructor's guide has a video component: video clips of students answering specific questions on the worksheet, accessed through hyperlinks that appear in the guide and accompanied by full transcripts. These videos have the potential to give instructors a vivid sense of how tutorials work and what they are really like for the students who experience them – what difficulties they have, what skills they bring to bear, and how they interact with

one another. Many of the video clips also show interactions between students and instructors. providing new instructors with diverse models of We originally envisioned these tutorial teaching. video clips as supplementing the in-person observations that a new instructor might make while learning to teach tutorials. We find, however, that the video clips in some ways go beyond what in-person experiences can provide: they can be played over and over again for detailed observation and analysis, and perhaps most importantly - they show what the students do when no instructor is present. (Abundant and sometimes incriminating evidence from the videotapes assures us that the students are not inhibited by the presence of the camera.) Text accompanying the video clips includes researcher observations intended to direct instructors' attention to features of interest.

TA Video Workshops

The video clips have the potential not only to help instructors in the ways described above, but also to serve as resources for professional development of teaching assistants. In order to facilitate the use of the video clips for this purpose, we provide "TA Video Workshops" that integrate tutorial excerpts, references to video clips of students working on that part of the tutorial. line-numbered transcripts, and discussion questions. Shorter workshops, with just one video clip, might structure a half-hour's discussion of a particular teaching issue; longer ones, with three or four video clips, show the development of students' thinking over the course of an hour-long lesson. We have found these video workshops to be useful at UM in weekly tutorial preparation sessions for physics graduate teaching assistants.

THREE IMPLEMENTATIONS

We provide our materials for free to anyone who requests them. We are interested to learn what uses people identify for the materials as well as how they implement the tutorials at their institutions. Three examples of such implementations are described below. These are not intended to represent "ideal" use; they are constrained by issues of class size, student motivation and preparation, instructor time and experience, curriculum, and so on.

Public Research University

A lecturer at a public research university in the Northeast, "Jim," used our tutorials in his introductory algebra-based physics course. Jim had a number of colleagues and graduate students in his department who were already experienced with *Tutorials in Introductory Physics*,¹ and thus was able to offer our tutorials in small recitation sections with adequate staffing, as at the University of Maryland. He used the materials exactly as provided (no modifications to the worksheets), but did not use the complete sequence of tutorials in the package; instead, he alternated our tutorials with *Tutorials in Introductory Physics*. Jim used ILDs occasionally throughout the semester, integrating them with his lecture room's infrared personal response system. He used the video workshops in weekly teaching assistant preparation sessions.

Jim felt that the tutorials worked fairly well in his course and were easy to integrate with the recitation sections already in place. Both standardized and course-specific assessments showed good conceptual gains by the students. Jim and his TAs, however, had mixed feelings about using our materials. They felt that the combination of instructional materials that they used (UM tutorials, UW tutorials, and other instructional strategies in other parts of the course) resulted in confusion for students about the course's priorities. Specifically, our tutorials' informal tone emphasis on intuition and building and epistemological questions were not reflected elsewhere in the course, and were sometimes not taken seriously by the students.

Public Comprehensive University

A professor at a public comprehensive university in the Midwest, "Kate," uses our tutorials in her introductory algebra-based physics course. Kate had prior experience with reform instruction through Context-Rich Problems,³ but had not used any tutorials before using ours. She does not have sufficient staffing for small recitation sessions; she teaches the class of 60-70 students either alone or with one undergraduate peer instructor. She therefore conducts the tutorials in a large class setting, alternating them week by week with context-rich problem-solving sessions. Her students work in small groups, but get only minimal feedback on their work (if any), since Kate and her one TA do not have time for sustained discussions with every student group. She does not conduct whole-class discussions because the student groups work at different paces. Kate's modifications to the tutorial worksheets have included removing the "checkpoints" (points where students are required to consult with an instructor before proceeding), since she was unable to enforce them. She also removed or reduced the equipment required for some tutorials. In another significant departure from the practice at UM

and UW, Kate collects and grades the tutorial worksheets, perceiving that her students will not participate in work that does not count directly towards their grade. She does not use the instructor's guide or video clips.

Kate is very happy with the tutorials and finds several of them to be ideally matched to her teaching. Like Jim, she has observed that the epistemological questions are unpopular with her students, and she finds it difficult to get her students out of a "right answer" mindset so that she can hear what they really think. However, she has no wish to remove the epistemological questions from the worksheets: she greatly values that feature of the materials and wants her students to engage in those questions. Kate wants more expertise in facilitating frank discussions of physics concepts and epistemological issues. At the same time, she feels that her expertise as a tutorial instructor has already increased. She has also been inspired to create new materials in a similar format (including a tutorial on coordinate systems).

Community College

A professor at a community college on the West Coast, "Pam," uses only one tutorial from our package (on Newton's second law) in her introductory calculus-based course. However, she has used it several times, making new modifications each round. and intends to retain it in her future teaching. Pam is experienced with reform instruction and integrates our single tutorial into a comprehensive program of other reforms to her course, mostly conceptual labs in the style of *RealTime Physics*⁴ and worksheets combining conceptual discussion questions with quantitative problems. Pam is the sole instructor in a class of 24 students; she has her students work in small groups, and leads a class discussion at checkpoints. Her modifications to the single tutorial that she uses include removing the epistemological questions, adding kinematic graphing exercises, and modifying language to promote clearer distinctions between acceleration and velocity and to improve readability for her many students who speak English as a second language. Pam does not use the instructor's guide or video clips.

Pam sees herself as having gained significant expertise as a result of her use of our materials, feeling that they have helped her come to recognize common student difficulties. She now sees "the whole thing about [students] being able to state different arguments" as a key step in conceptual change, and uses that insight elsewhere in her teaching.

Pam particularly appreciates the tone set by the modifiability of our materials and the fact that the developers welcome feedback and encourage modification. She says that "a lot of PER stuff is perceived as being exclusive...looking down their noses," and most PER materials are hard to adopt because they are "presented as just a done deal. So often PER stuff is presented as, you have to do it this way...it's a big turn-off."

DISCUSSION

The three implementations discussed above illustrate several implementation issues that, we hypothesize, are fairly typical. First, few users implement a curricular package as a complete set; they typically mix and match worksheets and other curricular materials from multiple sources. The modifiability of our materials makes it possible for instructors to try to minimize "epistemological" mismatches of the sort Jim encountered, or mismatches between tone, style, level, and so on.

Second, even when an instructor isn't modifying the substantive questions posed by a tutorial, she may still want to make minor modifications to adjust to local circumstances, such as Kate's eliminating checkpoints, or Pam's simplifying the language. Electronically-supplied worksheets make it easy for instructors to do this.

Third, as previous research indicates,⁵ instructors often make modifications even when curriculum developers try their best to enforce "faithful" implementation. For this reason, providing resources to help instructors make productive modifications partly by helping them understand why the developers wrote the worksheet as they did - may be more productive striving "faithful" than for implementations. In our judgment, the latest iteration of Pam's version of our Newton's second law material retains much of the spirit of the original version despite not following the "letter of the law," so to speak.

Fourth, as Kate and Pam's experiences illustrate, using tutorials and other reform-oriented instruction in a reflective way can itself serve as professional development. Pam's iterations of the Newton's second law tutorial reflect her evolving view of what her students need and how they learn, and it's not clear if her thinking could have evolved similarly were she unable to iteratively modify the tutorial. It's possible that such modifications could result in a disastrous experience for the students; but this doesn't appear to have happened in her case, and our instructor resources are designed to help instructors avoid lethal mutations.

In conclusion, we want to emphasize that we are not trying to promote our particular materials. As the three implementations show, in many classes, our explicit emphasis on epistemological development is either ill-suited or very difficult to implement. Instead, we hope to promote our *approach* to curriculum development, dissemination, and professional development. In this approach, users are encouraged to make modifications — to become, in a sense, co-developers; and the resources needed to facilitate implementation and to help guide effective modifications are integrated with the tutorials and interactive lecture worksheets themselves.

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