Promising Practices in STEM Education Essay Outline

Title: Use of Complex Problems in Teaching Physics
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Brief Description of the promising practice, activity or project:

Cooperative group problem solving is a generic instructional approach designed to scaffold complex tasks by using a cooperative framework among peers. The cooperative group framework is an important aspect of the practice and has a long history of learning success (Johnson and Johnson, 1989). Of the five key elements that separate cooperative groups from traditional groups, it is the Promotive Interaction element that warrants attention. Promotive Interaction reminds the teacher to structure the groups ***and*** provide the students with an appropriate task: a task that challenges the entire group.

In physics, cooperative group problem-solving, as introduced by Patricia and Ken Heller ((Heller, Keith, and Anderson, 1992; Heller and Hollabaugh, 1992) relies on Context-rich problems as the appropriate task for the groups. Context-rich problems always begin by putting the student (you) into an everyday situation; preferably written as a short story, where physics provides an answer. The goal is to motivate interest in the problem by using physics in a plausible situation. In such a manner, the general principles of physics are quickly applied to a concrete scenario. As they encounter more scenarios, they learn the generality of these principles. Two examples are given in another section.

Context-rich problems are closed ended, meaning that there exists a solution and there are only a small number of valid solution paths for the problem. The laws of physics and mathematics define those solution paths. This is opposed to open-ended problems, where even the solution path is to be determined (Reid and Yang, 2001). Such open-ended problems are common in advanced physics coursework or lab work, but for the introductory physics sequence, where students struggle with algebra as well as physics, such freedom seemed unwise. Furthermore, while solving a Context-rich problem should require decisions, the students need to know how to proceed from those decisions.

One of the important features of Context-rich problems is the plausible context; one where the student can envision themselves[1]. By demonstrating the usefulness of physics in a wide variety of situations, it is hoped that the students will see how to transfer these skills to their future endeavors: to be adaptive in their use of physics. Schwartz, Bransford, and Sears (2005), discuss balancing innovation and efficiency to create adaptive experts who can take what they know and do it well, but also do it in a manner that allows for creativity. The correct balance between the two provides the Optimal Adaptability Corridor for learning and transferring knowledge. While it has not yet been studied, Context-rich problems ought to be near this Optimal Adaptability Corridor by providing the students with the opportunity to make creative decisions, yet efficiently solve the problem.

Of course, students are generally not expert problem-solvers (Brandsford, Brown and Cocking, 1999). They enter classes with a variety of problem-solving misconceptions and poor strategy use in general. Another benefit of context-rich problems is that they require students to change their naïve strategies to be successful. For example, rarely is a Context-rich problem a one-step problem with only required

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[1] These contexts generally should exclude physics context since most introductory physics students will not become physics majors.

information in the problem. These two traits befuddle students who have had success with plug-n-chug strategies. Other naïve strategies can be similarly challenged making Context-rich problems an important tool for teachers whose goal is to teach problem-solving (Heller, Heller, and Kuo, 2004).

Having established the need and benefits for context in Context-rich problems, there is now the danger of having too much context. There needs to be a balance between enough context to permit useful decision making and too much context which breeds useless frustration. Foster (2000) demonstrated that there are 21 traits that when written into Context-rich problems add difficulty to the problem. These traits include extra information, vaguely defined goals, and important values that will eventually cancel. The traits find their origin in the research literature and validated in the study. Adding (or deleting) traits allow for the Context-rich problems to be adjusted based upon their use.

<u>Context of the Promising Practice</u>:

Cooperative group problem solving in physics has been demonstrated as a successful technique in both high school (Huffman, 1994) and in introductory college physics classrooms (Heller, Keith, and Anderson, 1992; Foster, 2000) although their use extends beyond the research to include classes up to graduate physics classes. The appropriate task that was used in these studies, Context-rich problems (Heller and Hollabaugh, 1992), can be found in mainstream college physics textbooks (Knight, 2008; Tipler and Mosca, 2007) which are used in both advanced high-school physics classes and introductory university physics courses.

Part of the versatility of context-rich problem is that they can be used in place of traditional problem in a variety of settings. Context rich problems have been used for small group work in classrooms and in instructional laboratories. They have also been used to challenge individual students on homework assignments and exams. By adjusting the difficulty of the problem, context rich problems can be used at anytime during the course, as either introductory problems or on the final exam assessing many concepts in the same problem.

One of the challenges of context-rich problems is that they are full of context, sometimes relevant, other times not. As such, students need to be able to parse the information and avoid distractions. This does put an additional cognitive burden on the students, but as previously discussed, this was an intentional design feature. Context-rich problems require literacy from the students. They need to be able to read, comprehend, and interpret the contexts. While there is nothing to prevent the context-rich problems from being translated into other languages, no research has been done on this. The lengthiness of the problem-statement is however one of the first concerns raised by faculty when given such a problem.

<u>Examples</u>: One or two concrete examples of how the practice is used.

Given on Midterm Exam, Fall 2008:

> While relaxing from studying physics, you watch some TV. While flipping through channels you see a circus show in which a woman drives a motorcycle around the inside of a vertical ring mounted on the ground. You determine that she goes around at a constant speed and that it takes her 4.0 seconds to get around when she is going

her slowest. If she is going at the minimum speed for this stunt to work, the motorcycle is just barely touching the ring when she is upside down at the top. She just makes it around without falling off the ring. How high up is she?

From Univ. of Minnesota Phys 1301 Laboratory Manual.

While examining the engine of your friend's snow blower you notice that the starter cord wraps around a cylindrical ring. This ring is fastened to the top of a heavy, solid disk, "a flywheel," and that disk is attached to a shaft. You are intrigued by this configuration and decide to determine its moment of inertia. Your friend thinks you can add the moment of inertial by parts to get the moment of inertia of the system. To test this idea you decide to build a laboratory model described below to determine the moment of inertia of a similar system from the acceleration of the hanging weight.

<u>What is the evidence that this is indeed a "Promising Practice"? What was Achieved /Demonstrated or Validated by Expert Opinion?</u> Heller, Keith, and Anderson (1992) reached several conclusions about cooperative groups problem solving, which have been further investigated by Huffman (1994) and Foster (2000).

- Mastery of broad content or concept: Students taught using cooperative group problem-solving with Context-rich problems outperform their national peer groups in mechanics concepts (Hake, 1998) and other physics concepts
- Skill development: Students who worked in groups saw an increase in their skill in approaching problems and in applying the correct concepts to problem-

situations. Likewise the performance of group solutions were superior to those produced by any individual member of that group.

- Affective domain: Only anecdotal evidence exists concerning student motivation and attitudes about context-rich problems. In general students take a while to accept the problems, but once they observe their own improvement they quickly become convinced of its usefulness.
- Behavioral changes: Likewise, only anecdotal evidence exists to support long-term behavior changes due to Context-rich problems. Nearly everyone who has taught using this methods has stories of students thanking them for teaching them how to solve problems.

Assessments:

The University of Minnesota has been refining the process of assessing problem-solving skills. What began as a simple rubric identifying a set of pre-defined skills from the expert-novice literature used in Heller, Keith, and Anderson (1992), was further delineated in Foster (2000), has matured into an easy to use scheme (Docktor and Heller, 2008). This instrument scores student performance on 5 domain-independent categories: (1) Useful Description (what representations are displayed); (2) Physics Approach (which general concepts applied); (3) Specific Application (How were concepts applied); (4) Math Procedures (were the rules of mathematics followed); and (5) Logical Progression (How was solution structured). Work continues on the refinement of this instrument. However, an artificial intelligence that could score student solutions would be a godsend.

The conceptual impact on focusing on problem solving in a class has also been assessed by using multiple-choice concept tests. When possible, nationally normalized concept tests are used, such as the BEMA (Ling, Chabay, Sherwood, & Beichner, 2006) and FCI (Hestenes, Wells, and Swackhamer, 1992). In these cases, cooperative groups problem-solving classes general score statistically better than their traditional peer classes. However, not every concept area is survey by a valid and reliable test. More work should be done to create these exams within a useful delivery mechanism.

What is missing is assessment that will enable a multidisciplinary research team to assess the skills, resources, and beliefs students carry into different settings and activate. In part such work is hampered by student mobility making following them longitudinally a challenge. But mostly it is a question of carefully designing transfer tasks that reflect a contemporary view of transfer (Mestre, 2005).

Next steps for developing/demonstrating effectiveness of the practice:

Cooperative group problem solving in physics has been established as a successful pedagogical tool when Context-rich problems are the appropriate task. However, there is plenty of room for further investigation.

- Context-rich problems have been discussed as a useful closed-ended task, but what of other tasks. Physics Education Researchers have developed two types of problems that warrant more investigation, specifically Jeopardy problems (Van Heuvelen, & Maloney, 1999) and WRONG problems (Harper, 2001). Both of these formats require decision-making, provide for creativity, yet still teach efficiency in problem solving. More research is needed to diversify appropriate tasks in physics cooperative grouping.

- Cooperative group problem solving has made its way into other disciplines. The Modeling Project (Jackson, 2008) uses small groups and whiteboarding in chemistry as well as physics. However, little systematic research has been done in supporting appropriate tasks outside of physics. There is a need to create and assess appropriate tasks in other fields of study.
- For all types of problems, regardless of discipline, the most important method of demonstrating the effectiveness of the practice is transfer. Do the students use the resources taught by this practice? Are the students adaptive and flexible learners because of the practice? The transfer question remains an open question for the cognitive side of cooperative group problem solving regardless of discipline.

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