

Sample Exams And Transfer In Introductory Mechanics

Carolann Koleci

*Worcester Polytechnic Institute
Department of Physics
Worcester, MA 01609*

Abstract. Why do novices use examples so extensively, no matter which subject area? Examples are often helpful because they reveal how to get from problem descriptions to theoretical re-formulations. Moreover, problem solving in semantically rich domains, like physics, requires one to translate a given problem description into theoretical concepts. We address some of the important issues of knowledge transfer, in the context of introductory mechanics, using data from an on-going sample-exam study conducted at Worcester Polytechnic Institute.

INTRODUCTION

The process of transfer is often defined as the degree to which learning contributes to or detracts from subsequent problem solving or the learning of subsequent instruction [1]. The ability to apply a particular skill, or bit of knowledge, to situations differing from those encountered during original learning is a signature of the transfer of learning [1].

It is documented in the cognitive psychology literature that problem solving and transfer are largely domain specific, thereby suggesting that transfer is not likely to occur as the result of general problem-solving instruction [2], but instead requires multiple practice opportunities in a variety of contexts [3].

A prevalent assumption of formal learning is the application of abstract principles and skills across multiple domains, with automatic transfer from the acquisition of these general skills. While some cognitive psychologists disagree that knowledge is entirely connected to the context in which it is learned [4], several researchers have evidenced that knowledge and transfer are strongly linked to context and domain [5-8].

To what extent does context play a role in students' ability to transfer knowledge obtained from an example to a new situation? Sample exams are very popular study aids exploited by students. Do they help or do they hinder the transfer of introductory physics knowledge, or is there no discerning effect?

METHODS

This study was primarily designed to ascertain the impact of examples in the learning of introductory mechanics by science, technology, engineering, and mathematics (STEM) students at Worcester Polytechnic Institute (WPI). A total of 69 STEM students were included in the introductory mechanics portion of this study. Subjects were not randomly selected so as not to deny any students the potential value of supplementary resources and extra credit for participation. This raises the issue of self-selection, and discussion on this topic is provided later in the report.

For both portions of this study, students were offered a quiz incentive for opting to do sample exams. Two days prior to each actual exam, participants were asked to complete the corresponding on-line sample exam and to *describe* the concepts behind each sample exam question (i.e., kinematics combined with application of Newton's 2nd Law). The recitation instructor then corrected all of the exams, offering students formative assessment. The graded sample exams were returned to students the day before the actual exam, and the sample exam was completely reviewed in recitation, thereby ensuring that most, if not all, students received the same amount of content instruction in recitation.

For each of the four exams, as part of the introductory physics recitation grade, students were required to complete a web-survey primarily, but not exclusively, to learn how they reviewed for each exam. As a quantitative form of summative

assessment, the Force Concept Inventory (FCI) was required (both pre- and post- tests) among all introductory mechanics students [9].

DISCUSSION

Several statistical tests were performed in order to determine the effect of sample exams on exam performance, and in order to address the issue of self-selection. The first table displays course content.

TABLE 1. Content for Introductory Mechanics

Exam One	Exam Two	Exam Three	Exam Four
Vectors and kinematics graphs	Projectile motion and Newton's Laws	Energy and momentum	Equilibrium, rotational motion, and angular momentum

For both portions of this study, a one-way Analysis of Variance (ANOVA) was performed, using normalized gain on the FCI as the dependent variable and choice to do the sample exam as the factor. These tests were performed to learn of any differences in conceptual understanding. For the case of introductory mechanics, statistically significant results were obtained for those students opting to do sample exam numbers one, two, and four. In all three of these cases, those students who complete each respective sample exam fare better on the FCI (normalized gain) than those not doing the sample exam ($p(\alpha = 0.05) = 0.04, 0.02, 0.04$, respectively).

While the above results may suggest that sample exams enhance the transfer of conceptual knowledge, as evidenced by statistically significant FCI scores, there is still the problem of self-selection. If more conscientious and academically astute students are selecting to do sample exams, then it is expected that these students will fare better on conceptual tests like the FCI. To address this issue, data from each of the two class populations was partitioned according to final course grade. In this manner, those students earning an *A* for the course and opting to do the sample exam could be compared with students earning an *A* for the course and *not* opting to do the sample exam. Analogous groupings could be made for *B*, and *C* students, respectively. Since the number of students failing the course is small, comparisons for these populations of the students can not be made.

When partitions are made according to final course grade, no statistically significant results are obtained.

This suggests that there is no significant difference in conceptual gain among like populations.

The second table consists of final grade, and average normalized gain, corresponding to the number of students in introductory mechanics.

TABLE 2. Final Grade versus Average Normalized Gain on the FCI

Final Letter Grade	Average Normalized Gain FCI	Number of Students
A	0.43	31
B	0.07	18
C	0.14	17

Do examples enhance the transfer of introductory physics problem solving as evidenced by exam performance? One-way ANOVA tests were conducted, with exam grade as the dependent variable and choice to do sample exam as the factor. In introductory mechanics, statistically significant results were obtained for tests two through four ($p(\alpha = 0.05) = 0.01, 0.00, 0.00$, respectively). These data suggest that in mechanics, sample exams are helpful for improving exam performance, at least 75 percent of the time, and dependent on course content.

To continue to address the issue of self-selection, the data set that was partitioned according to final course grade was used. When those introductory mechanics students earning a *C* for the course and opting to do the sample exam are compared with those students earning a *C* and *not* opting to do the sample exam, a slightly significant result is obtained for *Exam One* only. Those *C* students *not* choosing to do *Sample Exam One* performed slightly better on the corresponding exam.

Additional interesting results transcend from the compilation of web survey feedback. The on-line survey contains a series of questions asking students to compare sample exams with the actual exams, on a question by question basis. In addition to these questions, students are asked to indicate the manner in which they worked on the sample exam. For example, did they work independently, did they consult any of the various course resources for help, or did they work continuously, without interruption?

Survey data continues to support an unsurprising trend. Namely, the student-perceived degree of similarity, or isomorphism, between sample exam questions and that of the actual exam, influences the

level of successful problem solving. Students who perceive sample exam one, question one, to be similar to that on actual exam one are more apt to score higher than students who do not perceive the similarity. However, does this necessarily imply that students able to better recognize similar patterns are more apt to comprehend the underlying physical concepts? This question will, in fact, be discussed in a forthcoming publication.

CONCLUSION

There are several interesting research questions to be posed from this study. The first and foremost question is do sample exams enhance the transfer of introductory physics knowledge? Data obtained from this preliminary study suggests that the degree to which sample exams enhance both conceptual understanding and problem solving is context dependent, in support of work by many educational researchers [5-6].

In the context of introductory mechanics, material on sample exam one, two, and four appears significantly helpful for conceptual transfer.

For exam-performance transfer, in the area of introductory mechanics, material on sample exam two through four, inclusive, appears significantly helpful.

When data is further classified according to final course grade and factored according to conceptual gain on the FCI, no statistically significant findings arise in the context of introductory mechanics. When these data are factored according to exam grade, there is some evidence that *C* students not choosing to do sample exams fare better on the actual exams. What exactly do all of these observations translate to in terms of the usefulness and validity of sample exams?

Additional one-way ANOVA tests were performed, with final introductory mechanics grade as the dependent variable and choice to do corresponding sample exam as the factor. Statistically significant results were obtained for introductory mechanics tests one, two, and four ($p(\alpha = 0.05) = 0.04, 0.02, 0.04$, respectively). Do these results suggest that more academically astute students are opting to do sample exams, or do the sample exams help students to achieve better grades? In both of these courses, exams comprise seventy percent of the final grade.

Data compiled from the on-line survey only begins to address the issue of pattern recognition and similarity. Should the level of difficulty on the sample exam, as perceived by the students, match, falter, or surpass that of the actual exam? Follow-up studies include cross-comparisons between survey responses, FCI scores, GPA (minus final physics grade), and respective exam scores.

Future work will be to untangle the conundrum posed by considering cumulative grade point averages sans physics grades, in addition to interviewing students who do and who do not do sample exams.

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