The Impact of Physics Education Research on the Teaching of Introductory Quantitative Physics

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Abstract. During the Fall of 2008 a web survey, designed to collect information about pedagogical knowledge and practices, was completed by a representative sample of 722 physics faculty across the United States (a 50.3% response rate). This paper presents results of one part of the survey where faculty were asked to rate their level of knowledge and use of 24 Research-Based Instructional Strategies (RBIS) that are applicable to an introductory quantitative physics course. Almost all faculty (87.1%) indicated familiarity with one or more RBIS and approximately half of faculty (48.1%) say that they currently use at least one RBIS. Results also indicate that faculty rarely use RBIS as recommended by the developer, but instead commonly make significant modifications.

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INTRODUCTION

The last 30 years has seen the development and dissemination of many Research-Based Instructional Strategies (RBIS) for use in introductory college-level physics courses. Although substantial time and money has gone into developing these RBIS, little effort has gone into understanding whether typical physics instructors use or even know about these products. In this paper we describe and present the results of a web survey designed to document the degree to which Physics Education Research (PER) has impacted the teaching of introductory physics. This study was focused on college-level quantitative physics at two- and four-year colleges. By quantitative physics we are referring to the algebra- or calculus-based introductory physics classes that often go by the names of “college physics” or “university physics”. These have been the target courses for many RBIS and also represent the largest enrollments in most physics departments.

This paper will use data from the web-based survey to answer three questions:

1. Which RBIS do faculty know about?
2. Which RBIS do faculty use?
3. To what extent are RBIS modified during use?

METHODS

A web-based survey was developed by the authors in consultation with researchers at the American Institute of Physics Statistical Research Center (SRC). The survey consisted of 61 questions broken into 5 sections: 1) Introductory Screening Questions, 2) Your Teaching Situation, 3) Experience with and Attitudes Towards Teaching Innovations, 4) Your Instructional Goals and Practices, and 5) About You.

The survey was administered in Fall 2008 by SRC. Sampling was done at three types of institutions: 1) two year colleges, 2) four year colleges that offer a physics bachelor’s degree as the highest physics degree, and 3) four year colleges that offer a graduate degree in physics. SRC staff randomly selected institutions within each of the three types. Once selected, SRC staff asked department chairs to identify faculty who were likely to meet the selection criteria for the survey. Faculty were eligible for the survey if they had taught an introductory quantitative course in the last two years and were full time or permanent employees (i.e, part time, temporary faculty were not eligible).

Table 1 shows the number of institutions and faculty in the population and sample, the web survey response rate, and the number of faculty who responded to the survey. The overall response rate was 50.3%.

TABLE 1. Overview of population and web survey sample for faculty in each type of institution. Population estimates are from reports published by the AIP.

	Population Estimates		Response Rate	Useable Responses	
	# of Colleges	# of Faculty	% of faculty	# of Colleges	# of Faculty
Two-Year College	1072	2560	53.7%	128	186
Four-Year College w/ Physics Bachelor Degree	511	2700	50.6%	128	255
Four-Year College w/ Physics Graduate Degree	252	6300	48.2%	89	281

RESULTS

The third section of the web survey asked faculty to rate their level of knowledge and/or use of 24 specific RBIS. The following five categories were used: 1) I currently use all or part of it (current user), 2) I have used all or part of it in the past (former user), 3) I am familiar with it, but have never used it (knowledgeable nonuser), 4) I've heard the name, but do not know much else about it (little knowledge), 5) I have never heard of it (no knowledge).

How widespread is faculty knowledge about RBIS?

Table 2 shows the 24 RBIS ranked according to the percentage of faculty who indicated that they knew about the particular strategy. This includes current users, former users, and knowledgeable nonusers.

Figure 1 shows the percentage of instructors with knowledge of X or more RBIS. Overall, 87.3% of respondents report that they know about 1 or more RBIS while half (50.3%) know about six or more. Faculty from all types of institutions appear to have a good deal of knowledge about RBIS. However, as can be seen from Figure 1, there are some differences by type of institution. In general, faculty knowledge at B.A. institutions is higher than that at two year colleges or Grad institutions.

How widespread is faculty use of RBIS?

Table 3 shows the 24 RBIS ranked according to the percentage of faculty who said that they currently use the particular strategy.

TABLE 2: Ranking of the 24 RBIS according to level of knowledge (percentage of faculty who indicate that they are familiar with or have used the RBIS).

RBIS	All Institutions
Peer Instruction	63.5%
Physlets	56.3
Cooperative Group Problem Solving	49.3
Workshop Physics	48.2
Just in Time Teaching	47.7
Tutorials in Introductory Physics	47.0
Interactive Lecture Demonstrations	45.4
Activity Based Problem Tutorials	43.0
Ranking Tasks	38.7
SCALE-UP	34.5
Active Learning Problem Sheets	34.3
Modeling	32.7
Real Time Physics Labs	32.4
Context Rich Problems	30.4
Overview Case Study Physics	24.7
Open Source Physics	21.8
Investigative Science Learning Environment	21.1
TIPERS: Tasks Inspired by Physics Education Research	20.9
Open Source Tutorials	20.8
Video Lab	18.8
Workbook for Introductory Physics	18.5
Experiment Problems	17.3
Socratic Dialogue Inducing Labs	16.3
Thinking Problems	15.1

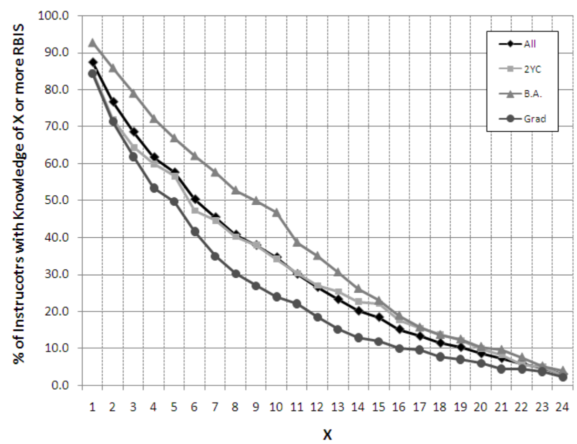

FIGURE 1. Ranking of the 24 RBIS according to level of Knowledge (percentage of faculty who indicate that they are familiar with or have used the RBIS).

Figure 2 shows the percentage of instructors who use X or more RBIS. Overall, nearly half (48.1%) of faculty say that they use 1 or more RBIS. As can be seen from Figure 2, there are some differences by type of institution. In general, faculty use at B.A. institutions is higher than that at two year colleges or Grad institutions.

TABLE 3: Ranking of the 24 RBIS according to percentage of current users.

RBIS	All Institutions
Peer Instruction	29.2%
Ranking Tasks	15.4
Interactive Lecture Demonstrations	13.9
Cooperative Group Problem Solving	13.7
Physlets	13.0
Just in Time Teaching	8.4
Context Rich Problems	8.3
Tutorials in Introductory Physics	7.9
Real Time Physics Labs	7.3
Workshop Physics	6.7
TIPERS: Tasks Inspired by Physics Education Research	6.6
Activity Based Problem Tutorials	6.0
Active Learning Problem Sheets	5.9
Experiment Problems	4.0
SCALE-UP	3.3
Modeling	3.2
Video Lab	3.1
Open Source Physics	1.9
Socratic Dialogue Inducing Labs	1.9
Overview Case Study Physics	1.7
Open Source Tutorials	1.7
Investigative Science Learning Environment	1.6
Thinking Problems	1.1
Workbook for Introductory Physics	0.9

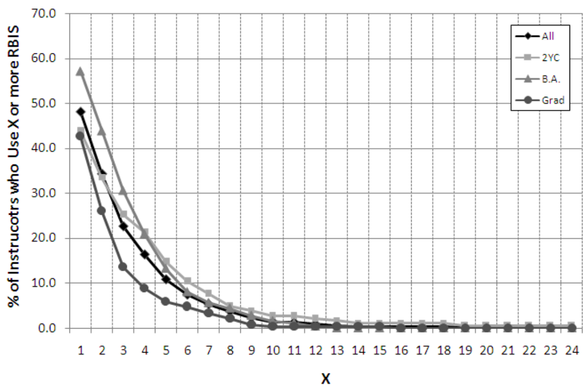

FIGURE 2. Percentage of instructors who report using X or more RBIS.

To What Extent are RBIS Modified During Use?

One tentative result from previous work by the authors is that physics faculty, when they do use a RBIS at all, do not typically take the RBIS and implement it 'as is' [1]. Rather, it appears much more common for faculty to take some of the basic ideas from a RBIS, but not implement the complete RBIS in the way described by the developer. The way faculty use a RBIS has significant implications for dissemination efforts. If faculty want ready-to-use RBIS and materials that they can implement as is, then curriculum developers should develop refined, tested curriculum materials and provide targeted and explicit instructions for how to effectively use them. On the other hand, if faculty want to customize a RBIS before use, curriculum developers should develop materials that are highly flexible and customizable and provide faculty with guidance about how to adapt the materials effectively.

For the web survey, the 24 RBIS were grouped into four clusters. In order to reduce respondent fatigue, we limited follow-up questions about RBIS use to two RBIS from each of the clusters: one that is used (if any) and one that has been used in the past (if any). The RBIS in each cluster were ranked by our expectation of the percentage of users based on a preliminary paper survey at the Summer 2008 AAPT meeting. If an instructor indicated use of more than one RBIS in a cluster, they would be asked follow-up questions about the use of the one that was highest on the list. Thus, we have information about use from all users of the top RBIS in each cluster and very little information from users of other RBIS in each cluster. It turned out that our predictions of the most commonly used RBIS in each cluster were correct. These RBIS are: Peer Instruction, Cooperative Group Problem Solving, Ranking Tasks, and Real Time Physics Labs.

According to Table 4, there may be differences in the degree of modification for each of the RBIS. Peer Instruction and Cooperative Group Problem Solving both have a sizeable percentage of users (47.9% and 41.0% respectively) who indicate that they have made significant modifications. This is much higher than the percentage of Ranking Task and Real Time Physics Lab users who report making significant modifications (21.2% and 21.3% respectively). There are many possible reasons for these differences that cannot be resolved with the data available from the survey. For example, one possible reason for the higher degree of modification of Peer Instruction and Cooperative Group Problem Solving is that these are both strategies that, to fully implement, require attention to, coordination of, and probably changes made to many aspects of the course. On the other hand, Ranking Tasks are flexible tools (innovative types of problems) that can be used within a variety of instructional styles. The developers of Ranking Tasks do not suggest one particular way to use these tools, but instead suggest a variety of ways that they might be incorporated into a course. In the case of Real Time Physics Labs, the relatively small percentage of instructors who make

TABLE 4: Extent of modification identified by self-reported users of all or part of each of four RBIS: Peer Instruction (PI), Ranking Tasks (RT), Cooperative Group Problem Solving (CGPS), and Real Time Physics Labs (RTPL). The percentages listed are the percentage of users within each of the RBIS categories who answered the question.

	PI (N=195)	RT (N=99)	CGPS (N=96)	RTPL (N=47)
I used it basically as described by the developer.	16.9%	33.3%	8.3%	25.5%
I made some relatively minor modifications	35.9	38.4	16.7	53.2
I used some of the ideas, but made significant modifications	41.0	21.2	47.9	21.3
I am not familiar enough with the developer's description to answer this question	6.2	7.1	27.1	0.0
All Users	100	100	100	100

significant modifications may be due to the ready-to-use format of the labs.

Later in the survey, instructors were asked to describe various aspects of their instruction. Of the 15 aspects of instruction asked about, 5 are particularly relevant to Peer Instruction. Based on the recommendations of the developer [2], a user of Peer Instruction would be expected to: 1) Engage in traditional lecture for nearly every class or multiple times every class, 2) have students discuss ideas in small groups multiple times every class, 3) have students solve/discuss qualitative/conceptual problems multiple times every class 4) have whole class voting multiple times every class, and 5) use conceptual questions on all tests. Only 6.2% of the self-described Peer Instruction users met all five of these criteria. With loosened criteria, 21.1% of the self-described Peer Instruction users met four or five of these criteria. Interestingly, the degree to which instruction matched the developer recommendations did not appear to vary based on the level of modification reported by the instructors. For example, 6.3% of respondents who said that they used Peer Instruction basically as described by the developer met all five criteria. This can be compared to 7.3% of respondents who said that they made some relatively minor modifications and 6.3% of respondents who said that they used some of the ideas, but made significant modifications.

Many of these same conclusions can be made for self-described users of Cooperative Group Problem Solving. Few users (14.5%) use four or five of the developer-described components.

DISCUSSION AND CONCLUSIONS

This study is the first attempt to document faculty knowledge about and use of RBIS relevant to the teaching of introductory quantitative physics. Results indicate that the development and dissemination efforts by physics education reformers have made an impact on the knowledge and practice of many faculty, but that there is significant room for improvement.

Faculty knowledge of RBIS appears to be relatively widespread. Almost all faculty (87.1%) are familiar with one or more RBIS. In addition, approximately half of faculty indicate that they are familiar with six or more RBIS.

Approximately half of faculty (48.1%) say that they currently use at least one RBIS. However, the level of use lags significantly behind the level of knowledge. This is an area that needs additional attention and study.

RBIS are typically not used as recommended by the developer. In addition, faculty do not always appear to realize the extent of modification they have made. Whether these modifications are likely to be constructive or destructive is not something that we are able to answer with the current survey data. The high level of modification suggests that additional work is needed to understand more about why and how faculty make these modifications. Because of the high level of modifications, PER change agents may be more successful in their efforts if they provide flexible curricula and provide substantial support and guidance during the implementation and customization process.

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