

PHYSICS EDUCATION RESEARCH SECTION

All submissions to PERS should be sent (preferably electronically) to the Editorial Office of AJP, and then they will be forwarded to the PERS editor for consideration.

A flexible homework method

Lei Bao^{a)} and Stephen R. Stonebraker

Department of Physics, The Ohio State University, 191 W. Woodruff Avenue, Columbus, Ohio 43210

Homeyra Sadaghiani

Department of Physics, Cal Poly Pomona, Pomona, California 91768

(Received 20 April 2004; accepted 16 June 2008)

The traditional methods of assigning and grading homework in large enrollment physics courses have raised concerns among many instructors and students. In this paper we discuss a cost-effective approach to managing homework that involves making half of the problem solutions available to students before the homework is due. In addition, students are allowed some control in choosing which problems to solve. This paper-based approach to homework provides more detailed and timely support to students and increases the amount of self-direction in the homework process. We describe the method and present preliminary results on how students have responded. © 2008 American Association of Physics Teachers.

[DOI: 10.1119/1.2955791]

I. MOTIVATIONS FOR CHANGING THE TRADITIONAL HOMEWORK METHOD

Many instructors consider homework to be an important part of the learning process. It is expected that by doing homework students will gain practice in problem solving, apply their knowledge to novel situations, gain a deeper and more robust understanding of important concepts, and maybe develop the skills needed to solve real-world problems that they may encounter in their future work place.¹⁻⁴ It is also expected that homework assignments with regular due dates help students to keep up with the pace of instruction.

There are many formats for assigning and grading homework. In large introductory physics courses, it is usual for instructors to assign approximately ten textbook problems due one week later. This work is graded and returned the following week. For a large class the grader might evaluate only a few of the problems in detail. Solutions are made available for all problems so that students can evaluate their work on the problems that were not graded. For the purposes of this paper, we consider this approach to be the “traditional” style of homework assignment and grading.

In a free-response survey we asked students to comment on this approach. Two common themes in their comments were that the traditional approach is inefficient, and the traditional approach does not provide enough support or feedback. For example, one student wrote “...I would like it if homework was less time consuming, and more informative.” And another student wrote “...I had no idea how to do it, and when I get it back, I would still not have any idea how to do it.”

In follow-up interviews we found that the traditional approach to homework had a negative effect on some students’ motivation. Posting solutions to the problems after they are due added little value because students typically felt they had no time to reflect on an old assignment but instead needed to

move on to the new one, which would be due in a few days. Several students expressed that their main concern was to have the homework done before the due date, and that they usually did not attempt to really understand the material.

Our primary goal in developing a new approach to homework is to improve its value as a tool for student learning. We wish to increase the quality and quantity of support that students receive while working on the assignment by providing high quality solutions to the problems before they are due. In addition, we allow students some freedom in choosing which homework problems to do. This paper describes the main features of our flexible homework approach and our first set of results, which focus on how students have responded to it.

In recent years, web-based online homework systems have been widely used. Although the work reported in this paper was primarily done within a paper-based homework system, we have been using the same methods and are observing similar results with our online homework systems.

II. THE FLEXIBLE HOMEWORK METHOD

Underlying our approach to homework is the assumption that students are mature and responsible learners who wish to understand the material and obtain a good grade. We explicitly inform the students that we think they are such people and that the homework assignments should be viewed as a learning tool rather than an assessment instrument.

We have experimented with several versions of the approach discussed here at The Ohio State University. The first experiment was conducted in the spring quarter of 2002 in a calculus-based modern physics class for first-year engineering honors students (a total of 85 students). Each assignment contained about 30 textbook problems. Students were told to choose any ten of these problems to submit as their homework. The complete solutions to all problems were given to

Table I. Homework quality ratings.

Rating	Students' behaviors
5	Submitted more than required number of problems over 80% of the time, worked in detail, and mostly A and B level problems.
4	At least 70% of the time worked in detail and submitted the required number of problems.
3	Incomplete solutions 50% of the time and usually B and C level problems, some copying.
2	Vague and incomplete solutions more than 75% of the time, mostly C problems, possible copying.
1	Submitted only a few problems, with large probability of copying.
0	No homework submitted.

students three to four days before the homework was due. The homework was not graded per se, but was assigned a quality rating from 0 to 5. The students were told that the quality of the homework would be judged based on whether they had made an effort to do the homework and on the completeness of their solutions such as showing intermediate steps.⁵ Students were told to work through the problems in their own way using the solutions as a guide if they wished, in much the same way that a humanities student might be expected to explain the contents of an article in their own words. The quality rating was assigned based on the types of behaviors defined in Table I. The homework rating counted for 7% of the students' grades.

Each of the problems in the assignment was labeled with A, B, or C to indicate their level of difficulty. Students were told that if they could consistently work out the A-level problems by themselves they were likely to receive an A in the class. In addition, we also told the students that 30%–40% of the exam problems would be very similar or even identical to homework problems. We expected that this arrangement would increase the students' motivation to work on the homework and that anyone who worked all the problems (about 360 in total for the course) would be very successful in the class. We found that many students worked more problems than they were asked to submit.

The second experiment was conducted in the fall quarter of 2002 in two calculus-based introductory mechanics classes for regular first-year students (a total of 350 students). Most of the designs, goals, and announcements to students were the same as in the first experiment. In this implementation each assignment contained about 20 textbook questions, which were divided equally into two groups. The solutions to the problems in Group I were given three to four days before the due date. The complete solutions to Group II problems were not given until the homework was submitted. During even-number weeks, we gave hints to each of the Group II problems before the due date. During odd-number weeks no hints were given. Students were told to submit ten problems each week, of which at least five had to come from Group II. As with the first experiment all problems were labeled A, B, or C to indicate their level of difficulty. The two groups of problems were selected so as to match as closely as possible in regard to content and context. The idea was to encourage students to study the Group I

Table II. Features of the flexible homework approach and their goals.

Design feature	Goal
Solutions given in advance.	Provide timely feedback and support to students so that they might engage in effective problem solving practice.
More questions than requested.	Allow students to make choices that personalize and hopefully optimize their learning.
Rating of difficulties	Allow students to monitor their own progress.

problems carefully (so that they might understand the physics behind them), and then apply what they learned to solve the Group II problems.

The third experiment was conducted in the first quarter of the fall of 2003 in our calculus-based introductory physics sequence for engineering honors students (total of about 230 students). The implementation was nearly identical to that in the second experiment. However, no hints were given and in addition to textbook problems we included context rich problems similar to those developed by the Physics Education Research Group at the University of Minnesota.⁶ The instructors' goals for the specific features of the flexible homework approach are summarized in Table II.

III. RESEARCH ON FLEXIBLE HOMEWORK ASSIGNMENTS

We discuss below some highlights of our research results on students' uses of this homework approach. The discussion is intended for instructors who are interested in implementing flexible homework and to encourage follow-up studies. We used several methods to probe students' reactions to a flexible homework approach including interviews, web surveys, and homework statistics. Seven individual interviews were conducted in the first experiment, which provided a rich collection of student comments and concerns on both the traditional and the new approach to homework. These were also used to help develop survey questions for obtaining large scale statistical data. Students' course work such as exams and conceptual survey results were also used as data in the analysis.

In the first two experiments, we gave students approximately three web surveys during the term, which included questions on the homework method. In experiments two and three students were asked to complete a web-based form each week in which they reported the particular homework problems they submitted. In experiment two we also asked students which problems they explored without submitting, as well as their views on the usefulness of these problems. We used these data to evaluate patterns of student behavior. Spot checks to compare the students' self-reported web survey data to actual homework submissions and one-on-one discussions with selected students indicated that the web survey data were valid.

According to the survey data, over 75% of the students preferred the flexible approach to homework over the traditional approach. Students reported that they were more relaxed, happier, and more motivated doing their homework: "Now I am not doing it to get it done by the due date, but rather to really learn it." "With new homework, I have more

motivation. I used to give up doing homework when I would get stuck on one problem. I like the new method. I have references when I am struggling.”

Some of the students also saw this approach as a way for them to learn how to solve problems like an expert: “The new method allows students to see how difficult problems are done and the systematic method in solving them ... to apply the same methods to solve difficult problems of their own.”

There are possible drawbacks to this homework approach. Students can simply copy the entire solution. However, our analysis suggests that most students (>70%) seem to use the solutions very responsibly: “We all know that we can copy the homework, but it doesn’t do us any good.” In addition, survey results indicate that students believe the flexible homework approach is one of the two most important components of the course (along with recitation) in regard to impacting their performance on exams.

For research purposes, students’ submitted homework was rated based on completeness and effort. In the first two experiments we chose one recitation section (~25 students) to study in detail. In the first experiment we found that students who consistently did their homework with higher quality also achieved better scores in the course. In experiment two we observed no correlation between students’ homework quality ratings and their final grades. This lack of correlation is not surprising because homework is only one part of instructions, and its impact on student learning may depend on the population and educational setting.

In a survey near the end of the term we polled students about their methods of choosing homework problems to submit. Students were asked if the following characteristics encouraged or discouraged them from trying a problem: For each of the items, students rated it in terms of encouraging, neutral, or discouraging. (1) It came early on the list (i.e., you do the first few listed). (2) It was rated as being easier. (3) It was rated as being harder. (4) It was a “question” instead of an “exercise” or “problem.” (5) My friends chose the problem already. (6) The problem used or asked for a graph. (7) It sounded interesting. (8) I need to practice problems of its type. (9) The posted solution of that problem was clear to me [Group I only]. (10) The posted hint for that problem was clear to me [Group II]. (11) The problem’s numerical answer is in the back of the book [Group II].

The results for 341 students are shown in Fig. 1. We see that “interests” and “practice” influence student choices. We also see that students choose problems that are rated easy and/or have solutions or hints available. One interpretation of this behavior is that most students do not like to challenge themselves. Another is that they do not find getting stuck or frustrated productive. Students also choose problems they find interesting and pick some more challenging problems. We are hopeful that this finding indicates our flexible homework approach might help students to balance challenge and frustration.

In the third experiment we asked students how many problems beyond the required ten they typically attempt to solve. Seventy eight percent responded that they attempt at least two additional problems. Most likely, these are problems that they attempt but then give up on in contrast to problems that they solve after their assignment is completed. Nonetheless, we consider this a benefit to the students. The data also

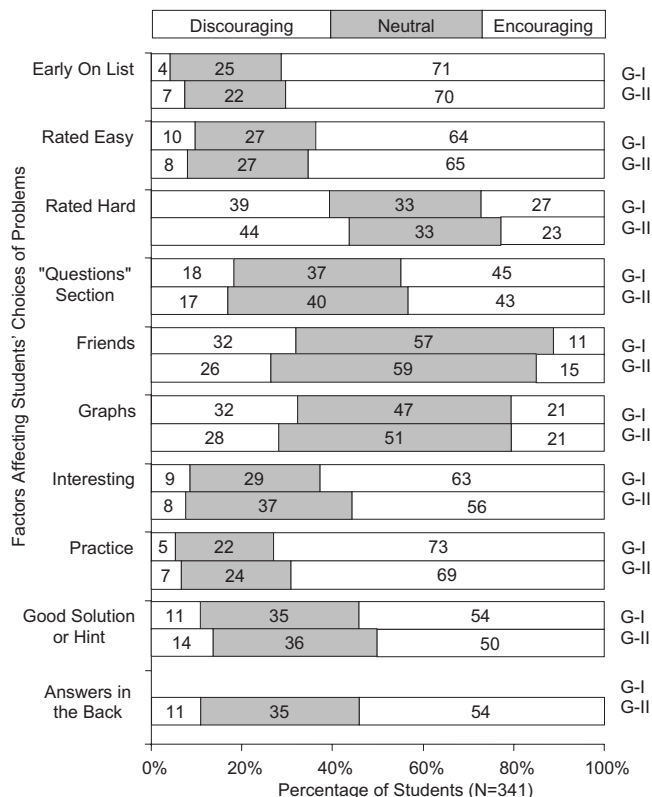


Fig. 1. Factors that affect students’ choices of homework problems.

showed no correlation between students’ final grade and the level of difficulty of the problems that they choose.

In the flexible homework approach solutions are intended to serve as surrogate tutors, answering questions that the students might have as they work. Near the end of experiment two, we surveyed the students asking “Describe the manner in which you use the Group I solutions and Group II hints. For example, do you read them before thinking about the problems? Or refer to them only when you get stuck? Or simply ignore them completely?” We collected 337 responses. We found that 221 (66%) students read the Group I solutions only when they are stuck or are done with a problem in order to check their work; 59 (18%) students read the solutions either before or while working; 16 (5%) of these students specifically stated that they read through once, then set the solution aside and try to recreate it; 46 (14%) students report that they do not use the Group I solutions at all. Very few students made specific comments about the hints for Group II problems.

Over 80% of the students we surveyed believed that having solutions before the due date helped their learning. Their views were split over whether to provide complete solutions to all problems or to provide solutions to only some of the problems.

It is interesting to see how such views may be different for students with different performance in the class. Figure 2 shows the relation between students’ final grades and their preferred format for the homework.

We also asked the students to estimate how many hours per week they spent looking over the solutions for homework problems in Group I and Group II. The results are shown in Fig. 3 for students with various final grades.

In addition to results on students’ behaviors when given

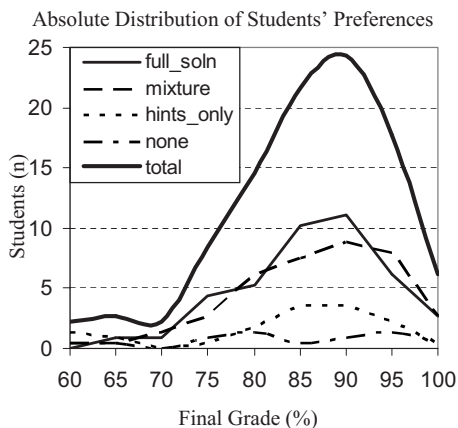


Fig. 2. The relation between students' final grades and their preferred formats of homework.

the freedom of the flexible homework approach, we have some student performance data which also suggest that the flexible approach might be more effective than the traditional. In first quarter engineering honors physics courses taught in two consecutive years (year 2 and year 3), we implemented flexible homework. The classes in year 1 prior to the implementation of flexible homework used a traditional homework approach⁷ which included some nontraditional context rich problems. For these three years there was an overlap of at least one lecturer from year to year. Two-tailed nonpaired *t*-tests on the incoming students' background scores show no significant differences ($t < 0.05$). After their first quarter of physics, all students were administered the Mechanics Baseline Test (MBT).⁷ Scores for the treatment groups (year 2 and year 3) are 5%–7% higher at a very good significance level ($t < 0.01$).

IV. SUMMARY AND IMPLICATIONS

Our preliminary study of a flexible approach to assigning and grading homework found that most students preferred the new approach rather than the traditional approach. Preliminary results indicate that better students may make more constructive use of the method than students with a lower level of achievement even though most students submitted work of similar quality. The statistics on students' prefer-

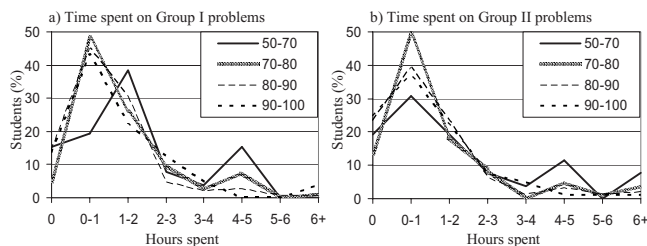


Fig. 3. The relation between students' final grades and the time spent on reading the solutions of the Group I and Group II problems. There are four grade ranges (50%–70%, 70%–80%, 80%–90%, and 90%–100%). The percentage of students in different grade ranges can be seen from Fig. 2. (a) Relative percentage of the time spent on reading Group I problems. (b) Relative percentage of the time spent on reading Group II problems.

ences indicate that good students prefer to have all the solutions before the due date while mid-level students prefer a mixture of hints and solutions. Students reported that they tried to use the Group I problems and their solutions as examples to study expecting that practicing on these problems would help with solving the Group II problems for which no solutions were given.

As a result of this study, we believe a mixture of solutions and no-solutions is the best format for our population and educational setting. Additional suggestions for use of this approach include:

- (1) Avoid listing the problems in the same order as the textbook, because students tend to choose the first few problems to do. Providing twice as many problems as the students are required to submit is excessive; very few students make it to the end of the list when choosing problems. Providing 150% of the number of questions required for submission is sufficient to satisfy the students' desire for freedom, while saving instructors the trouble of writing solutions for problems that very few students will attempt.
- (2) Match Group I and Group II with similar problems to promote practice-and-apply type of behavior.
- (3) Solutions prepared based on known research results are preferred. For example, the solution might address several different types of alternative (often naive or inappropriate) ideas and methods that are commonly seen among students.
- (4) Provide a balance of A, B, and C level problems with diverse settings and requirements.

At this time more than a dozen classes at The Ohio State University have used the flexible homework approach. The implementation of this approach requires little if any change to an existing course and can be easily implemented elsewhere.

ACKNOWLEDGMENTS

We thank Neville W. Reay, Gordon Aubrecht, Gordon Baugh, Leonard E. Jossem, Alan Van Heuvelen, and other members of the Physics Education Research group at The Ohio State University. This work is supported in part by NSF grants Nos. REC-0087788 and REC-0126070.

^a)Electronic mail: lbao@mps.ohio-state.edu

¹Beverly Swanson, "How important is homework?" Educational Research Information Center Archives, (www.eric.ed.gov/archives/homework.html).

²R. Dufresne, W. J. Gerace, P. T. Hardiman, and J. P. Mastre, "Constraining novices to perform expert like problem analyses: Effects on schema acquisition," *J. Learn. Sci.* **2**, 307–331 (1992).

³B. J. Duch, "Problem based learning in physics: Making connections with the real world," *AIP Conf. Proc.* **399**, 557–565 (1997).

⁴P. Heller and M. Hollabaugh, "Teaching problem solving through cooperative grouping," *Am. J. Phys.* **60**, 637–644 (1992).

⁵The quality of the homework is difficult to determine accurately. The announcement made to the students is primarily for the purpose of letting them know that we are watching what they do.

⁶See <http://groups.physics.umn.edu/physed/Research/CRP/crintro.html>.

⁷D. Hestenes and M. Wells, "A mechanics baseline test," *Phys. Teach.* **30**, 159–165 (1992).