Phased-Array Homework: Used to Shape and Steer
Student Understanding

Stacy Godshall

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Abstract

Students demonstrate different levels of understanding of material which often coincide with how diligent the students are with their daily preparation prior to class. Having them attempt homework problems prior to class enables them to be better prepared to ask specific questions about concepts and also better prepared to perform on exams. This paper will introduce “phased-array homework” which is a flexible system of assigning homework which also incorporates specific timing of publication to students of “partial solutions” for their reference. As the name of the homework system implies, phased-array homework (PAH) allows an instructor to shape and steer student understanding in much the same way that a phased-array antenna allows for the shaping and steering of a transmitted electromagnetic signal to yield its subsequent effective radiation pattern. Implementation method and results will be presented as well as student perspective on the system.

INTRODUCTION

In this paper, an alternate method for assigning and grading homework that is designed to give homework more of an impact on student motivation and performance will be presented. In addition, this method is one which allows for greater flexibility of assessing and reinforcing of key concepts by the instructor. The inspiration for this method was in part, my experience at the Combined Arms and Services Staff School, at which I was introduced to the “Re-do”, as it was called by my small group leader at that school. The phased-array homework (PAH) method, much like the “Re-do”, is intended to be a vehicle for more in-depth student understanding of material by way of learning from mistakes and correcting those mistakes in a timely manner. Guiding students through the timely correction of mistakes is a way in which to measure the process of learning instead of the typical way of assigning and grading homework which measures the end result of the learning or the lack thereof [1], [2].

Different levels of student understanding often coincide with how diligent a student is with his/her daily preparation. There are many ways to inspire students to prepare daily, however when they attempt homework problems prior to a particular class, students are prepared to ask
specific questions about specific concepts. A challenge, particularly for a physics class comprised of mostly students who are not math, science, or engineering (MSE) majors, is guiding students in obtaining needed problem solving skills and confidence to attempt problems for which they are learning the concepts for the first time. In essence, providing them with the skills and attributes needed to become a successful independent learner. There is, and may always be, some question of whether graded homework has a positive effect on the test performance of students [3]. However, there have been several studies that have attempted to determine this by way of alternate homework methods. It is these alternate methods that were additional inspiration for the PAH method employed in this study.

LITERATURE SURVEY

The way in which we assign and grade homework could greatly enhance the likelihood of students becoming successful, independent, active learners. There are many advantages to “flexible homework” which allow for tailored approaches to assigning/submitting specific homework problems in a homework set [4], [5]. Bao and Sadaghiani’s flexible homework system shows positive results in motivation and performance. Their flexible system also provided hints to some problems and solutions to others all prior to the due date of the assignment [4]. Homework systems like the flexible homework system are becoming more prevalent in order to achieve a number of goals which align with several practices for education suggested by Chickering and Gamson [6]. Five of those principles are 1) Providing prompt feedback, 2) Encouraging contact between faculty and students, 3) Developing cooperation among students, 4) Encouraging active learning, and 5) Communicating high expectations [6], [7]. There are also benefits to allowing students to correct their own mistakes, which is a principle encouraged by Davis [7], [8]. In fact, the alternate grading method which allows students to leverage self-correction of their work after some initial feedback from the instructor was employed with some success in the area of student motivation and in peer collaboration in three mechanical engineering classes at the US Military Academy [7].

As opposed to Bao and Sadaghiani’s flexible system which provides hints and full solutions to some problems, other systems employ a method of providing imperfect solutions to students in order to have students analyze their work and determine where the flaw is in the imperfect solution and/or their own solution [8]. This method addresses very well the aforementioned principle of immediate feedback and also the notion of reinforcement of correct understanding [9], [10]. When this method is employed however, the instructor cannot allow for the direct opposite to occur, namely the reinforcement of incorrect understanding [9]. The imperfect solution method enables students to critically assess his/her own work and the possibility of reinforcing incorrect understanding is mitigated during classroom discussion about the problems [9]. In the discussion of his method, Armstrong mentions that this approach is contrary to Skinner’s learning model in which a false statement is rarely presented to a student so as to avoid reinforcement of incorrect understanding [9], [10].
Yet another approach to improve several of the aforementioned education principles, specifically student cooperation/interdependence, is to have a designated subset of students in the class be responsible for publishing a set of solutions to a homework set [11]. Eschenbach calls these solutions the “Beautiful Homework Solutions” and has a different group of students develop and publish them each week [11]. This method has many positive aspects to include the above mentioned interdependence of students, development of independent learning, pseudo peer-feedback, and less instructor feedback required. The latter of these two strengths to this method are ones which would be very beneficial to alleviating faculty concerns of the amount of grading they would have to perform with more graded homework. This is a concern that has seemed to always accompany the question of whether to employ graded homework or not. In fact, this question of the instructor resources needed to grade the aforementioned homework and possible alternatives to mitigate the strain graded homework places on instructor resources have been discussed [12]. The method of peer-assessment would reduce some of the instructor resources on grading. In addition, peer-assessment allows for the evaluation by one student of scientific information presented by another student and thus fosters professional development for future work by the student [13]. This method would also address the needs of a program that has a program outcome of a student that can critically assess scientific and technical claims and comment on their validity as is the case for the core physics program at the US Military Academy. Murthy employed peer-assessment by way of having students follow a grading rubric at MIT with some success [14].

**RESEARCH METHOD**

The PAH method for assigning and grading homework has inspired cadets at the US Military Academy enrolled in introductory physics to be more diligent with daily preparation and be more confident with their problem solving abilities. The method used throughout the last three terms was to start by assigning homework sets, each comprised of four to ten problems each. These homework sets were assigned, in general, two lessons before they were due. The problems were chosen from those in the course outline and as such were ones that the course director had chosen as important problems from each block of instruction for the course.

The way in which the problems were chosen was based on three things: 1) the current level of understanding of the respective class section of the current material; 2) the number of problems that had accompanying WileyPlus online resource assistance such as GO tutorial problems, Interactive Learning Ware (ILW) problems or those that had a solution in the Student Solution Manual (SSM) (all of which are provided for a limited number of problems through the textbook publisher’s website); and 3) the amount of review that the respective section needed on previous material. This problem selection process thus is one in which several problems are chosen from a large array of possible problems which all meet the learning objectives for those respective lessons. This is analogous to a phased-array antenna because this allows for an instructor to target specific learning objectives which need reinforcement and/or emphasis thus steering the students understanding to an intellectual “location/position” where the student needs
to be focused. In addition, it allows an instructor to proverbially shape the “battlefield” a.k.a. the next lesson in that the assigned homework can include specific learning objectives for which the instructor knows may be challenging for them specifically. This process also allows the instructor to obtain a thorough assessment of cadet understanding of the material at the very start of the class so as to immediately address any conceptual gaps.

Once assigned, the cadets were told that there would be two phases of turning in the assignment. During phase one, the cadets were to attempt the problem prior to discussing the associated material in class. It was required that the cadet attempt at least the first six steps of the “Physics Problem Solving Process” that we teach cadets to use. The steps of the process include the following:

1) Read the problem carefully
2) Visualize the situation and draw a sketch
3) Write down the given information
4) List all valid assumptions
5) Write down the quantity that you are tasked to solve
6) Identify the fundamental physics concepts and select the physics equations that will be the most useful in solving the problem
7) Solve the problem
8) Verify the solution by addressing reasonability, units, and significant figures.

If the cadet showed all steps of the problem solving process and obtained all the correct answers, which were provided at the time of the issuing of the assignment, they turned in the assignment and they received 100% of the points associated with that assignment. If however, they did not obtain all the correct answers, the homework set was self-graded in class so that each cadet would obtain immediate feedback and be able to ask questions on portions they did not understand. This required the cadet to mark their own (Phased Homework) PHW with a 30% of the maximum points. This 30% represents a grade of the attempt only, not a grade of the correctness of the assignment. This would constitute and complete phase one of the phased process. If a cadet only earned a 30% then they were afforded the opportunity to conduct phase two and re-work the PHW, turning it in the very next lesson for a maximum possible 90% of the maximum points. If they chose not to re-work their PHW and learn from their mistakes, they would earn a 30% total possible marks. The earning of either a 90% or 30% would complete phase two of the multi-phased process. Thus this process became a highly-encouraged, two-phased homework process which allowed cadets to learn from their mistakes and immediately correct them. Immediately correcting mistakes allows the cadet to quickly adjust their mental
model of a physical situation and how to properly solve the problem. In each of the two phases, the first attempt and then the re-worked attempt, the cadets were allowed to use any and all available resources such as those WileyPlus resources aforementioned and also any current partial solutions posted on the SharePoint site. Phase two could be turned in at a later date for point reduction if the cadet needed additional attempts to correct their mistakes. Thus a cadet was highly encouraged to continually correct their work until they completely and correctly solved the problem.

RESULTS AND DISCUSSION

This method was implemented in three consecutive terms as follows. First, in the spring term 2010 in PH202 in which the total course enrollment was 995 students. One instructor implemented the PAH process in four sections of the course. The four sections, sections A15, C15, G15, and I15, combined were collectively labeled section 15. There were mixed results of this approach; however the performance of section 15 overall was better than that of the average of all of PH202 cadets during the spring 2010 term as shown in Figure 1. The section with PAH performed better on Phase Line Writ 1 (PLW1), Phase Line Writ 2 (PLW2), Written Partial Review 1 (WPR1), and the WPR1 re-enforcement writ. Upon further analysis, it is evident that three of the four hours (A, C, and G) had higher averages than section I15. If the I15 averages had been commensurate with A, C, and G Hrs, then the entire section 15 averages would be higher than that of the PH202 course-wide averages for most of the major graded events. Part of this disparity for I15 stems from their underperformance on graded homework. The homework average for I15 was five to ten points lower than the other three hours’ averages. This shows that there is a direct correlation of their diligence to daily preparation in the form of graded homework and their performance on the major graded, course-wide events.

![Graph showing the effectiveness of PAH in PH202 Academic Year 10-2](image)

Figure 1: The comparison of the performance of section 15 (Group with PAH) to that of all PH202 cadets on all the major graded events and the final course average for the spring term of 2010.

Note: n = 62 for the group with PAH, and n = 995 all sections combined.
This method was also implemented in the subsequent fall term in PH201. In this iteration, the total course enrollment was 999 cadets and the group size that used PAH was 50 cadets. Again there were mixed results when comparing the PAH group results to the overall course averages. As indicated in figure 2, the group with PAH performed better on two of the three major graded events and slightly lower on the final exam. The final overall course average for the group with PAH was just slightly better than the entire enrolled cadet final grade average.

![Figure 2](image)

Figure 2: The comparison of the performance of section 4 (Group with PAH) to that of all PH201 cadets on all the major graded events and the final course average for the fall term of 2010. Note: n = 50 for the group with PAH, and n = 999 all sections combined.

The PAH method was again implemented in the spring term 2011 in PH201 for which the total enrollment was 72 and the PAH group size was 43. The PAH group was comprised of sections A1, C1, and G1. During this iteration, the control group that did not use PAH was comprised of 29 cadets. The control group was compared to the PAH group on four course-wide graded events; the Written Partial Review 1, the Written Graded Review, the Written Partial Review 2, and the Phase Line Writ. WPR 1 and WPR 2 were exams of 150 points each and the WGR was a midterm exam of 450 points. This iteration again yielded mixed results, as shown in figure 3, with the PAH group only performing better on three of the four major graded events.

Overall the averages for the group using PAH on all major graded events with the exception of WPR2 was higher than that of the control group. Upon further analysis of the section by section performance, it was determined that one section’s (G1) performance on homework was the leading cause of the drop in the performance of the PAH group on WPR2. Had G1 had averages that were commensurate with A1 and C1, then the entire section 1
averages would be higher than that of the PH201 control group averages for all of the major graded events. Part of this disparity for G1 stems from their underperformance on graded homework. The homework averages for G1 were substantially lower than the other sections averages. Recall that this same effect of one section’s underperformance partially affected the results from PH202 in the spring of 2010. This shows that there is a direct correlation of student diligence to daily preparation in the form of graded homework and their performance on the major graded, course-wide events.

Figure 3: The comparison of the performance of section 1 (Group with PAH) to that of the control group on all the major graded events and the overall average for the spring term of 2011.
Note: n = 43 for the group with PAH, and n = 29 for the control group.

Since one section had a habitually, substantially lower homework grade, it was necessary to remove that section from the comparison between the control group and the PAH group. In fact, there were a large number of cadets in G1 which did not complete a majority of the PAH assignments which was a primary cause of their systemically lower performance on the course-wide events. Removing G1 from the PAH group yielded results which indicate that the PAH group performed better on all major graded events. Furthermore, the combined average (i.e. the WGR and WPRs) of the PAH group increased by just over 4% by removing G1 from the PAH group.
Even though these three iterations cover two different courses over three different terms and thus have different populations and course material, there is evidence of the potential benefit of this method as manifested by a majority of the scores being better than the control group and/or the entire course averages. The major limiting factor to the positive impact on the student scores on the exams was their motivation to complete the homework assignments. As was discussed, there were two sections, one in the spring of 2010 and one in the spring of 2011, which, when they actually completed assignments, habitually performed worse on those assignments. One variation for the PAH in the spring of 2011 was that there were a larger number of problems that had partial solutions available after phase one was completed. This allowed cadets that made mistakes in phase one to reference a solution that was only omitting certain steps and thereby they could independently correct their mental model. This in turn allows the student to retain the correct physics and solution methods for that problem more thoroughly.

An additional trend evident in all three iterations was that the averages on course-wide graded events that occurred later in the term, i.e. WPR2 for PH201, were lower than those in the beginning of the term. Part of this was due to the topical coverage, but also in part due to homework performance during that respective time period. In both terms for PH201, a majority of cadets made a deliberate decision to turn in less of the PAH assignments due to more heavily weighted events in other courses at the same time. This was evident by comments on a survey conducted after WPR2 in the spring 2011 term of PH201. In that survey, cadets admitted they
needed to allocate more time to courses and events that would have more impact on their grade for those courses than the PAH assignment did for their physics class. Additionally, it was evident by the average number of cadets not turning in a PAH assignment going from three cadets before the WGR to nine cadets before WPR2.

In addition to the impact on student learning and retention, it was necessary to consider if the PAH method affected such things as student motivation, confidence level, and overall satisfaction. There are several methods to collect data for analysis of this type of classroom research, such as interviews, web surveys, tests, exams, and observations of student homework [5]. There were several survey questions that were posed to the cadets after the spring 2010 and fall 2011 terms about this homework process. These questions were posed to determine if the cadets gained more confidence from the process and if they felt that the process helped them to understand the material better. The results of these surveys indicate that the PAH process indeed does allow cadets to gain confidence, better understand the material, and become more motivated to solve physics problems. These results are shown in figures 5-8 as follows.

![Figure 5: End of course feedback question addressing confidence gained by the homework process.](image)
Figure 6: End of course feedback question addressing understanding of the material via the PAH process.

Figure 7: End of course feedback question addressing motivation to solve physics problems as a result of the homework process.
From the survey results, 88% of the cadets were more confident in solving physics problems as a result of the PAH process; 85% felt that the process assisted them in understanding the material; 83% were more relaxed about the homework grade and more motivated to solve physics problems; and 86% were satisfied with the process. Many students acknowledged in an additional survey taken during the spring 2011 term that they had not taken advantage of the PAH process for WPR2 as they should have.

CONCLUSION

One concern that many faculty members may have about this and any graded homework process is the temporal resources that are needed to grade homework. The combination of a self-graded phase one coupled with the expectation to correct mistakes until the correct answer is achieved mitigates these concerns. This is because cadets are diligent in seeking assistance when needed and will utilize all resources to achieve success. If an instructor has homework sets that are nearly perfect will spend less time grading than on a homework set that is very incomplete.

This method of revising work until the correct answer is achieved also fosters a good work ethic that will persist throughout the cadets academic career and beyond into his/her profession as an officer.

Overall, this phased-array homework process was very beneficial and allowed for great section by section analysis of how the cadets were preparing daily and how that level of diligence translated to their respective major graded event performance. There were aspects of the method that need more refinement. In particular, there needs to be a redistribution of points associated with each PAH set to mitigate the increase in the number of uncompleted assignments just before WPR2. Making these PAH sets near lessons 19-25 worth more will also emphasize the importance of rigid body dynamics which is covered during that time. This is needed as this topic is historically the most challenging for cadets in PH201. Additionally, the number of solutions which have partial solutions posted after phase one need to be increased. Lastly, the
partial solutions need to have more of a scaffold. Specifically, the amount of the solution that is provided needs to be more limited as the term goes on toward lessons 25 and beyond. This will wean the cadets off of this resource and enable them to transition more effectively to a truly independent learner. The presented Phased-array Homework process is one which is a good alternative to instructors who desire to access and evaluate the learning process as opposed to just the end result of learning. Lastly, the PAH process is a good alternate method to provide prompt feedback, encourage contact between faculty and students, develop cooperation among students, encourage active learning, and communicate high expectations of life-long independent learners.

REFERENCES


