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Optimizing homework for high-aptitude students

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Abstract
Previous research on homework has produced mixed results regarding its effectiveness in boosting student performance. Bhandarkar, Leddo and Banerjee (2016) found that giving average-aptitude students homework produced much larger increases in performance than giving the same homework assignment to high-aptitude students. Standard homework assignments may offer little more than repetition of what high-aptitude students already know, thereby doing little to boost performance. The present study tested the hypothesis that giving high-aptitude students more challenging homework assignments would lead to higher performance than giving them standard homework. This hypothesis was tested with 17 high-aptitude high school students who were about to take a college level calculus course. They were taught how to solve problems involving related rates, a topic often applied to real world problems. After the lesson, nine were given a standard homework assignment and eight were given a more challenging homework assignment. After doing the assignment and having it reviewed by the instructor, students were given a post-test. Results showed that students receiving the more challenging homework assignment scored significantly higher than those receiving the standard homework assignment. Results suggest that high-aptitude students may advance more quickly through their courses and potentially be able to achieve higher levels of learning if challenged more with their homework assignments. Implementing this in a school setting may require a departure from the standard practice of giving all students the same assignments.

Keywords: homework, calculus, aptitude, high school, test performance

1. Introduction

Over the years, considerable research has been done looking at the factors that affect students' academic performance. The primary incentive for conducting such research is to identify interventions that could potentially boost human performance. The amount of time students study affects students' grades greatly [1]. How students manage that time also plays a huge role in their grades [2]. The amount of class effort correlates with performance on tests and class work [3]. Parents' education, family income, self-motivation, age of students, learning preferences, class attendance, and entry qualification are factors that have a significant effect on students' accomplishments in a certain amount of time and performances on tests, especially in public institutions [4].

One factor that has received considerable attention is homework. Given that homework is an integral part of our educational system, it is only natural to investigate whether and the extent to which doing homework boosts student achievement. A number of factors related to homework have been investigated. One factor that has been investigated is amount of time spent on homework. Here, the literature has produced mixed results, with some researchers [5, 6, 7] finding a positive correlation between amount of time spent on homework and academic performance, while others [8] finding no significant correlation between amount of time spent on homework and student performance. In some cases, a negative correlation between homework and performance was observed [9, 10, 11].

While Patron and Lopez [8] did not find a statistically significant relationship between total study time and performance, they did find a statistically significant relationship between consistency in the amount of study time and performance. Hayward [12] found that simply having teachers review homework assignments does not increase student achievement by itself, but if students correct their homework errors as part of the review process, their achievement goes up. Hayward also found that quality homework that takes up an appropriate amount of a student's study time can prove to be very advantageous. If homework takes an inappropriate amount of time, the positive effect on student performance completely evaporates [13]. On the other hand, students with higher ability levels have been shown to spend less time on their homework compared to students with average aptitude [14]. Moreover, Grodner and Rupp [15] found that the benefit that homework provides depends on the quality of the student effort. If students work diligently on their homework, they derive more educational benefit than when they do not. An intriguing study by Eren and Henderson [16] found that students benefit more from doing homework in math than they do from doing it in English, science or social studies.

Other researchers have looked at the contribution of homework in the context of other variables that could affect performance. For example, Schuman, Walsh, Olson & Etheridge [17] found that there is at best only a very small relationship between amount of studying and grades as compared to the considerably stronger and more monotonic relations between grades and both aptitude measures and self-

reported class attendance. Keith [18] conducted a path analysis to model the effects of a variety of factors (including ethnic, personal, and school-related factors) on student achievement. Quality of coursework and student aptitude turned out to be the two largest predictors of success while homework only had a small positive effect.

Bhandarkar, Leddo and Banerjee [19] hypothesized that one reason for the inconsistent findings regarding homework and academic performance is that high-aptitude students generally do not benefit much from doing homework as they have already learned the material in class, while average-aptitude students benefit more from the extra practice that homework provides. In their study, Bhandarkar *et al*. gave both high and average-aptitude students classroom instruction in basic trigonometry, which was followed by a test to measure how much they had learned. As might be expected, the high-aptitude students scored much higher on this test than did average-aptitude students. Students were then given a standard homework assignment on the topic, which was then reviewed with them by the teacher. Students were given a post-test (the equivalent of a unit exam). The results showed that the average-aptitude students showed strong improvement in performance after doing the homework assignment, while the high-aptitude students showed little improvement. The latter result was not the result of a ceiling affect as the mean score on the post-test was still well below 100%.

The results of the Bhandarkar *et al*. study raise some interesting questions about high-aptitude students. Clearly, even high-aptitude students show room for improvement after initial instruction. However, currently, educational practice seems to be to give them the same homework that the rest of the class receives and rely on repeated exposure to the material to increase performance to the near perfect levels that high-aptitude students typically exhibit on their report cards. This raises the question as to whether a different type of homework, such as more challenging problems, could lead to more rapid improvement in the performance of high-aptitude students.

Accordingly, the present study seeks to compare the effectiveness of standard homework problems vs. more advanced homework problems on the performance of high-aptitude students. The hypothesis is that high-aptitude students receiving advanced homework problems will perform better than those receiving standard homework problems. This hypothesis was tested in high school students who were getting ready to take a college level calculus course.

2. Methods

2.1 Participants

Participants were 17 high school students recruited from high schools within Loudoun County, Virginia during the summer of 2018. All students were rising 12th graders who were scheduled to take Advanced Placement Calculus (AP Calculus), a college-level course, the following fall. Since AP Calculus is a college-level course, all participants were above grade level in math and were, therefore, considered to have above-average aptitude in mathematics. Participants responded to a flyer advertising a free calculus workshop to prepare them for their upcoming calculus course. Participants were not paid for their participation.

2.2 Materials and Procedure

Materials consisted of a pre-test, instructional materials, the homework assignments and a post-test. The pre-test covered four problems and the post-test consisted of eight problems covering the calculus topic of related rates. Both pre-test and post-test consisted entirely of word problems. The instructional materials consisted of notes to the instructor, a lesson on related rates taken from Khan Academy [20] and in-class practice problems taken from www.mathfanatics.com [21]. There were two versions of the homework problems. One version was designated as the standard homework set. If consisted of both multiple choice and simple related rates word problems. The second version was designated as the enrichment homework set and was considered harder. It consisted entirely of word problems involving rate changes in more complex situations than those described in the standard homework set.

Participants were first given the pre-test to insure that they had not already mastered the topic of related rates. Once screened, participants advanced to the instructional phase of the study. Nine were assigned to the standard homework set condition and eight were assigned to the enrichment homework set condition. Participants were instructed individually by a single teacher who gave the same instruction to each student. Instruction consisted of teacher-led instruction, having the participants go through the Khan Academy lesson and the Math Fanatics practice problems. At the conclusion of the instruction, students were given their respective homework assignments, which they completed in the same session so as to control for the possibility that participants might seek supplemental instruction on related rates at home. At the conclusion of the homework assignment, the teacher went over the participants' assignments. This was followed by having the participants take the post-test.

3. Results & Discussion

Participants' work on the post-test was scored on an all or nothing basis. The total number of correct answers was tallied for each participant. The mean number of correct problems solved by homework type (standard or enrichment) is shown in Table 1.

Table 1: Mean Post-Test Scores of Participants in Standard and Enrichment Homework Conditions

Condition	Mean Post-Test Score
Standard Homework	6.22
Enrichment Homework	7.13

As can be seen from Table 1, participants in the standard homework condition solved, on average, 78% of the post-test questions correctly, while those in the enrichment homework condition solved, on average, 89% of the post-test questions correctly. Both groups did well, considering no partial credit was given for problems and the post-tests were delivered after a single instructional session, rather than after several classes as is often the case in classrooms.

It turns out that the variability in the data for each condition was small. Participants in the standard homework condition solved between five and seven questions correctly and Participants in the enrichment homework condition solved

either seven or eight questions correctly. Therefore, in spite of the small sample size, the difference in performance between the two groups was statistically significant, t = 3.42, df =15, p =. 0038.

4. Conclusion

The present findings support the hypothesis that giving high-aptitude students more advanced homework assignments leads to higher performance than giving them standard homework assignments. This extends the previously cited work of Bhandarkar, Leddo and Banerjee [19] that found that providing standard homework assignments benefited average-aptitude students much more than it did high-aptitude students. Even though it is difficult to make direct comparisons, it is interesting to note that in the Bhandarkar *et al*. study, high-aptitude students scored on average approximately 73% on their trigonometry post-test after receiving standard homework, which is fairly close, percentagewise, to the 78% average score of the present high-aptitude students on their related rates post-test after receiving standard homework.

The rough consistency in performance across students who received standard homework between the studies suggests that standard homework assignments do not maximize high-aptitude student performance and leave considerable room for improvement. On the other hand, giving high-aptitude students more challenging homework problems resulted in post-test scores of 89%, which is the equivalent of a full letter grade higher in performance after just one assignment.

Classroom experience shows that most high-aptitude students typically achieve scores of at least 89% on their unit tests. Therefore, it is reasonable to assume that participants in the present study would have achieved performance levels of 89% or higher if they continued to receive instruction and homework. Therefore, providing high-aptitude students with challenging homework problems may not ultimately lead to better grades in school. This, however, does not mean that there is no benefit to giving high-aptitude students more challenging homework. The benefits of doing so might be realized in other ways.

First, as indicated in the present study, challenging homework may lead high-aptitude students to achieve mastery of subject matter more quickly. If this is the case, high-aptitude students may be able to cover more subject matter within the same course schedule than they currently do, particularly when they take courses with average-aptitude students that are "taught to the middle." Second, challenging homework may allow high-aptitude students not only to reach mastery of existing subject matter more quickly, it may also allow high-aptitude students to achieve even greater levels of proficiency that are normally covered in a standard course.

Both of these possibilities make for interesting research questions that can be explored. If high-aptitude students can master subject more quickly by doing more challenging homework, can they cover more topics within the same course and will they be able to master even more challenging problems, perhaps those involving real world applications of the material they are learning, than what is normally covered in the course? The other research issue worth exploring is whether enhanced mastery of the subject matter resulting from challenging homework enables students to progress even farther within a subject than they might ordinarily do, e.g., by taking more advanced courses such as multi-variable calculus. If such results turn out to be the case, then there may be some systemic changes that would be needed in how schooling is conducted. The upper grades of high school may largely address this by offering students Advanced Placement courses that are naturally geared for high-aptitude students. However, many times, the lower grades employ a "one-size-fits-all" approach to education where each student receives the same instruction and homework within a classroom. Many school districts do have gifted and talented programs, but it may be the case that further customizing the educational experience each student needs to his or her ability might optimize how much that student learns. The notion of customized education is very intriguing and potentially one with far reaching implications.

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