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Comparing the relative effects of homework on high aptitude VS average aptitude students

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Abstract
Previous research on homework has produced mixed results regarding its effectiveness in boosting student performance. One factor that may be mediating these results is that homework may have different effects on students based on their aptitude. High aptitude students may grasp concepts when they are initially taught and may derive little benefit from reinforcing what they already know through homework. Average or lower aptitude students may not initially fully grasp what they have been taught and may benefit from the additional practice that homework provides. This predicts an interaction effect between aptitude and homework on student achievement. This hypothesis was tested with 38 middle school students who were taught trigonometric concepts. Students were divided into high and average aptitude groups based on an initial assessment. They were then taught the concepts and tested to measure their performance. Students were then assigned homework, which was reviewed with them. Students then took a post-test to measure final performance. Analysis of the data showed main effects for group and homework as well as an interaction effect showing that homework benefitted average aptitude students more than it did high aptitude students. Results suggest that schools may need consider departing from the standard practice of giving the same assignments to each student in a given class and find more creative ways to insure that each student receives the type of homework that will greatly boost the student's educational achievement.

Keywords: homework, trigonometry, aptitude, interaction effect, middle 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 reseachers [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 (2011) 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 (2010)[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 (Cooper and Valentine, 2001) [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 (De Jong, Westerhof, & Creemers, 2000) [14]. Moreover, Grodner and Rupp (2013) [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 (2011) [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 (1985) [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 (1989) [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.

We believe that student ability or aptitude can help explain the inconsistent results found in the literature regarding the relationship between homework and student performance. Normally, in school, a teacher teaches concepts to students and then assigns homework as a way to reinforce the classroom learning. Such reinforcement could reasonably be expected to provide benefit to the extent to which a student has not yet mastered the concept that was taught. Therefore, if a student already understands the concept, there may be little to no benefit from doing extra practice through homework, but if the student does not yet grasp the concept, then extra practice through homework should be beneficial Therefore, we hypothesize an interaction effect between student aptitude and doing homework on student performance. We expect that high aptitude students would see little to no improvement in academic performance as a result of doing homework whereas average or low aptitude students would see a large benefit from doing homework. This is consistent with Keith's (1982) finding that low ability students who spent one to three hours on homework each week achieved the same grades as average ability students who spent no time on homework.

This hypothesis was tested with middle school students who learned new trigonometric concepts. A study was conducted in which middle school students were assessed to determine whether they were high or average aptitude in math, then given instruction in the trigonometric concepts, given a mid-test to determine what they had learned, and then given a homework assignment that was reviewed, followed by a post-test.

2. Methods

2.1 Participants

Participants were 38 middle school students recruited from the Herndon, Virginia area. Of the participants, 23 were boys and 15 were girls. All students were rising 7th or 8th graders. Participants responded to a flyer advertising a free trigonometry workshop and were not paid for their participation. The flyer was placed at the MyEdMaster tutoring center and also at the local library.

2.2 Materials and Procedure

Since the present hypothesis predicts a difference in the effectiveness of homework based on student aptitude, it was important to find a way to group students based on their aptitude. Accordingly, students first took a 30 minute, 40 multiple choice Level 8 (eighth grade) Math League test. The Level 8 Math League test is a national, competition-level math test developed by Steve Conrad, Dan Flegler, Adam Raichel, and former members of the College Board's Mathematics SAT II Test Development Committee and the American Mathematics Competition Committee that primarily includes algebra and number sense problems. The version given to the students was the 2004-2005 test to minimize the likelihood that students would have seen the test before and we verified at the time of administering the test that no student had previously seen it. The test itself can be viewed at http://www.mathleague.com/ml-files/grade_8_2004-05_contest.pdf.

To determine the relative aptitude of the students, we used a score of 30 questions correct as a cutoff for those to be considered "high aptitude" math students. 30 was chosen as the cutoff since it is the threshold that Math League itself uses in determining whether students who take the test are eligible for an award. As a result of the test, 18 students (12 boys and 6 girls) were assigned to the average aptitude group and 20 students (11 boys and 9 girls) were assigned to the high aptitude group. The relative distribution of students to aptitude group may not be that surprising since Herndon is located in Fairfaix County, Virginia, which has one of the top school districts in the United States.

After students completed the Math League test, they were given a pre-test to insure that they did not already know the trigonometry concepts that would be taught in the experiment. The pre-test consisted of seven multiple choice questions, each with four possible answer choices. The multiple choice format was used because in Northern Virginia (where the study was conducted), Algebra II is a high school level course and the local high schools often use multiple choice formats for tests. The seven questions covered the basic principles of SOHCAHTOA (sine equals opposite over hypotenuse; cosine equals adjacent over hypotenuse; tangent equals opposite over adjacent). The highest any student scored on the trigonometry pre-test was two questions out of seven, which was not statistically different from chance. Therefore, no student was eliminated from the experiment because he or she appeared to already know the material.

After the pre-test, students received 45 minutes of instruction in basic trigonometry. The instruction consisted of both lecture and problem solving. The same instructor was used for all students and the instructional materials were prepared ahead of time to insure instructional consistency across students. Instruction was done in small groups of up to five students to simulate a classroom setting. Students were allowed to ask questions on what was being taught. At that point, the aptitude tests had not been scored so neither instructor nor student knew what group the student was assigned to. This also created a situation where high aptitude and average aptitude students were taught together, thus reflecting the reality of most classrooms. The instructor had not been previously acquainted with the participating students. These precautions were taken to avoid a potential Rosenthal effect [19] whereby the instructor might interact with a student differently based on perceived aptitude of the student.

After the instruction was completed, the students were immediately split up and given a mid-test. The mid-tests were proctored to avert potential cheating. The mid-test consisted of 12 multiple choice questions, each with four possible answer choices. Four questions covered right triangle trigonometric ratios using SOHCAHTOA, four questions covered common SOHCAHTOA applications (coordinates on a unit circle and angle of elevation/depression problems), two questions covered inverse trigonometric functions and two questions covered the reciprocal trigonometric functions (cosecant, cotangent, and secant). Students were not given feedback regarding their performance on the mid-test, nor did the instructor see the results.

After the mid-test, students were given a lunch break, during which there was a proctor to insure that students were not independently seeking to learn more about the topic using online or other resources. After the lunch break, students completed a 15-problem homework set that was comprised of five right triangle SOHCAHTOA questions, four SOHCAHTOA application questions, three inverse trigonometric function questions, and three reciprocal trigonometric function questions. Consistent with standard homework assignment practices, these questions were not multiple choice and required the student to calculate the answers to their questions. Students were also given as much time as they wanted to complete the homework set. When they were finished, the instructor reviewed the homework with the students on an individual basis and corrected any mistake they made. Finally, students were given a post-test of 12 multiple-choice questions, each with four choices, that was roughly the same difficulty as the mid-test with the same number of problem types as occurred in the mid-test.

3. Results & Discussion

The number of correct answers given by each student on the mid-test and post-test were tallied. The mean mid-test and post-test scores for each group of students is shown in Table 1 below.

Table 1: Mean Mid-Test and Post-Test Scores of High and Average Aptitude Students

Groups	Mid-Test Average Score	Post-Test Average Score
High Aptitude	7.3	8.8
Average Aptitude	3.28	7.83

At first glance, the pattern of results seems to support the hypothesis, namely, that the average aptitude students seemed to show a large gain in performance after completing their homework assignment, whereas the high aptitude students showed a very small gain in performance. To test whether these results were statistically significant, we performed a 2 x 2 analysis of variance (ANOVA). The experiment employed a mixed design with unequal N's with groups (high vs. average aptitude) as a between subject variable and test scores (mid-test vs. post-test) as a within subjects variable.

The results of the analysis showed that there was a main effect for group, with high aptitude students generally scoring higher than average aptitude students, $F(1,72) = 49.5$, $p < .001$. This is not surprising since the groups were initially created based on performance on the pre-test. Similarly, there was a main effect for homework on test performance with students generally performing better on the post-test than on the pre-test, $F(1,72) = 69.3$, $p < .001$. Comparison of mid-test vs. post-test scores using a Wilcoxon signed rank test with continuity correction for both the high aptitude and average aptitude students revealed that post-test scores were higher than mid-test scores for both groups of students, $p < .001$ for both groups. This suggests that homework is beneficial for both groups of students.

The most interesting question is whether students in different groups showed differential benefit from homework as this was the main hypothesis of the experiment. To test this, we look at the group x test interaction, which was significant, $F(1.72) = 18.6$, $p < .001$. These results suggest that homework benefitted students of average aptitude more than it did students who were high aptitude. In this case, performance more than doubled for students in the average aptitude group while improving roughly 20% for those in the high aptitude group. The results could not be explained simply due to a ceiling effect as the high aptitude students averaged 7.3 out of 12 after the mid-test, clearly providing room for improvement.

4. Conclusions

The results of the study suggest that while doing homework can help students in general improve their academic performance, the benefits of doing homework are much greater for high aptitude students than for low aptitude students, thus confirming our hypothesis. However, since the high aptitude students still had significant room for improvement after the mid-test, the present results cannot be explained by a ceiling effect. This is somewhat contrary to the initial argument presented at the beginning of the paper, namely that homework would not benefit high aptitude students because they already mastered the material after the initial instruction.

Therefore, the present results invite additional investigation as to why high aptitude students show only modest benefit from homework compared to average aptitude students. One possible explanation may lie in high aptitude students' perception of their knowledge. If a student feels that he or she already understands the material after the initial instruction, that student may be less motivated to see homework as an opportunity to learn and improve on performance. If the student puts in less effort, he or she may derive less benefit. This may cause the learning curve for high aptitude students to rise more steeply at first and then flatten out.

If this analysis is correct, then the implication is that homework assignments should focus on inducing high aptitude students to learn new things rather than simply reinforce what was already taught in class. Since high aptitude students do not appear to completely master a complex topic after one learning session, an ideal homework assignment for those students may be to find ways to apply those concepts to real world problems that force the students to integrate new concepts. For example, once a student has learned the basics of trigonometric ratios, they could be given homework problems that require application of those ratios to engineering problems such as bridge design where they have to use those ratios to compute how much weight the bridge can support. Additional research is needed to determine the best ways to use homework to optimize performance of students of different ability levels. This would represent a departure from our current educational model where all students in the same class tend to get the same homework regardless of aptitude or current level of proficiency. Instead, schools may need to find more creative ways to individualize homework assignments to insure that each student can optimize the educational benefit of the homework assignments received.

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