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Incentives and Their Effect On Retention and Comprehension of Mathematical Ideas

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Abstract

The purpose of this study is to demonstrate the benefits and/or disadvantages of providing rewards to students as a result of understanding and applying mathematical concepts during class time and on assessments. Rewarding student behavior by means of incentives have been used in the past to reward behavior and less on content knowledge. The goal was to analyze the effects of incentives on retaining and comprehending mathematical concepts. After analyzing the data, it was proved that providing incentives did not have a significant impact on demonstrating knowledge of mathematics.

Introduction

Throughout my K-12 education, I have seen many of my teachers attempt to incentivize students for understanding mathematics. However, while the original intention of these incentives is to reward those students for understanding mathematics, these incentives could be considered to be behavioral rewards for those students who needed some form of encouragement to learn or recognition of their efforts in class. I recognize that throughout the entirety of a school year, students will need to be incentivized to increase their engagement in math class, but oftentimes, students are more concerned with receiving the reward rather than understanding the content. Based upon Skinner's behaviorist theory (Skinner, 1938), a student's behavior will most likely change when a reward/incentive is presented in the form of an ultimatum. This issue is something that I have been fascinated to research. For my study, I wanted to investigate whether or not these incentives teachers have provided to students in the past were potential means to reinforce mathematical concepts, or were they used as behavioral mechanisms to reward students for positive behavior towards math.

Literature Review

Prior to conducting this study, I gathered some research that had already been done on my topic. Incentives can be defined as, according to the Cambridge Dictionary, "Something that encourages a person to do something…" (n.d., Cambridge Dictionary). Incentives have been used as behavioral mechanisms in order to increase the tendency of a person to complete a task or achieve a goal. According to an article published by the University of California-Berkeley, students are often concerned with their self-image and the fear of failure. This plays into students having to be incentivized to get good grades as these incentives can increase a student's chances of having less doubt about their self-image and their behavior towards school. Teachers have commonly used incentives in order to have their students be more engaged in their learning, but there has been no proof that incentives assist with understanding and retaining content. This is what this study is investigating. Over the course of my research, from the sources I have gathered, the general consensus is that using incentives in the classroom are beneficial for both teachers and students, but have no relation to demonstrating knowledge of content in any subject.

Beginning with teacher incentives, according to the book *Incentives to Improve Teaching: Lessons from Latin America*, researchers Emilia Vegas and Ilana Umansky discovered there was a large push for teachers working in the Latin America countries to incentivize teachers to grow as educators in order to maximize student achievement. Incentive policies were categorized into 3 different groups: policies regarding teacher preparation and professional development, policies regarding longevity of a teacher staying in the profession, and policies regarding the work that teachers perform on a day-to-day basis. The first incentive that was used across all teachers in Latin America was an incentive on one's salary. The book then analyzed the trends across several countries within this region including Mexico, Chile, Bolivia, and Brazil. In Mexico, teachers would receive anywhere from a 24.7% wage increase (after the first promotion) to a 197% increase (after the fifth promotion). However, based upon the students' standardized test scores, the researchers found that, "…no apparent effect… on student performance" (Vegas, 2005). The same relationship held for teachers who received similar wage increases and students' standardized test scores in Chile, Bolivia, and Brazil. Therefore, the researchers concluded that providing salary increases after each promotion did not have a positive (or any) increase in the amount of student achievement. The second incentive that was used were programs that were geared towards developing teaching quality and student learning. There were two programs that were compared: the EDUCO program and the PROHECO program. The EDUCO program was developed and implemented in El Salvador and this program incentivized teachers by allowing teachers to have more control over their classroom and the way the students were taught instead of having school administrators dictate how their classroom should be ran. While there was not a specific pay incentive attached to this program, the program produced some positive results with the most notable of them being that students performed higher than non-EDUCO program schools in learning Spanish. Regarding the PROHECO program, which was developed in Honduras, teachers were paid less than schools not in the program and worked more hours compared to those in the EDUCO program. This particular program did not promote any kind of incentive for teachers and, ironically, still scored higher in math, science, and Spanish exams compared to non-PROHECO schools. Therefore, the researchers concluded that regardless if incentives were or were not introduced for teachers within these two programs, students would continue to score higher on standardized exams compared to students not in these programs. Overall, it seems that rewarding teachers does have an impact on student achievement, but the main goal of this study was to determine whether or not providing incentives to *students* would produce similar results.

When considering incentives for students, according to an action research project completed in 2016 (McClean, 2016) that considered providing incentives for students in order to analyze behavioral patterns among students, the author mentions two common terms: tangible rewards and intangible rewards. According to the author, tangible rewards are rewards that students can use such as, "…prizes and gifts" (McClean, 2016). Intangible rewards are rewards that correlate to an intrinsic motivation. Some of these include, "…words of affirmation and encouragement" (McClean, 2016). The author clearly suggests that providing such rewards will increase a student's ability to be motivated in school and would provide a much needed boost for students who tend to struggle or dislike learning mathematics. In this study, I chose to explore using tangible rewards (specifically, using candy) as it relates to retaining and comprehending mathematical concepts. Additionally, the author discusses the concepts of extrinsic and intrinsic motivation. As defined in the study, “Intrinsic motivation refers to the engagement in an activity with no reason other than enjoyment and satisfaction of engagement itself (The Gale Group, 2003)” (McClean, 2016) and “…extrinsic motivation refers to being engaged in an activity for the sake of earning something (Giles-Brown, 2010)” (McClean, 2016). As I consider this study, the goal of providing these incentives relates to the concept of extrinsic motivation. However, the goal of this study was to demonstrate whether or not providing incentives for students correlates to retaining and comprehending mathematical ideas, not motivation.

Throughout my study, the majority of instances when incentives were provided was when students used proper mathematical vocabulary, demonstrated strong procedural fluency and conceptual understanding, or when students were able to identify errors in reasoning. One method I used in order to assess this was by utilizing class discussions. According to an action research study written by Cecelia Reddington in 2006 (published to NYU Steinhardt in 2019), a reward system was implemented in order to study the effectiveness for students in sixth grade to participate more willingly in classroom discussions. How this system was set up for the students was that for every 5 instances in which a student participated in a class discussion, the student would receive a raffle ticket. At the end of a unspecified amount of time, all of the raffle tickets would be placed into a container and one ticket would be pulled out. The student whose ticket was selected had permission to play board games and socialize with their peers during one lunch period. In sum, these incentives were used to encourage students to engage in constant participation. In this study, I did incorporate classroom discussions, as you will observe in the methodology section. However, the intention of these discussions was not to encourage students to participate, but to contribute to the discussion in a meaningful way by utilizing proper mathematical vocabulary and procedures.

According to a study done in 2008, incentives were used in order to increase engagement in events that occurred outside of the classroom (American Psychological Association, 2008). This particular article highlighted some related terminology that was seen in the McClean article (such tangible and intangible rewards and extrinsic and intrinsic motivation). In this study, teachers provided students with tangible rewards such as field trips, gift certificates, and other recreational activities in order to increase the motivation and participation of their students during after-school activities. At the conclusion of this study, it was proved that these specific incentives lead to higher participation in after-school activities. When considering the study I conducted, I created a hypothesis that was very similar to the conclusion in this study. In the methodology for this study, my hypothesis will appear but instead of relating the use of incentives to participation in activities (which concerns student behavior), the hypothesis will be related to demonstrating retention and comprehension of mathematical concepts.

Methodology

The study was conducted over a 10-day period consisting of 1 unit in Algebra 1 related to solving systems of linear equations. Prior to the study, I selected two Algebra 1 classes that were relative in size (i.e.: similar number of students). My first class had 23 students and my second class had 18 students. The first class I selected would act as the “control group” where no incentives were provided based upon their mathematical comprehension during in class discussions and assessments. The second class I chose would act as the “experimental group” where incentives were provided by the instructor’s discretion based student use of mathematical vocabulary and procedures. Some situations in which incentives were present included students using proper mathematical vocabulary (such as, but not limited to, systems of equations, substitution, elimination, slope-intercept form, standard form, etc.). When constructing this study, I hypothesized that students in the experimental group would perform better than the students in the control group because of the presence of incentives.

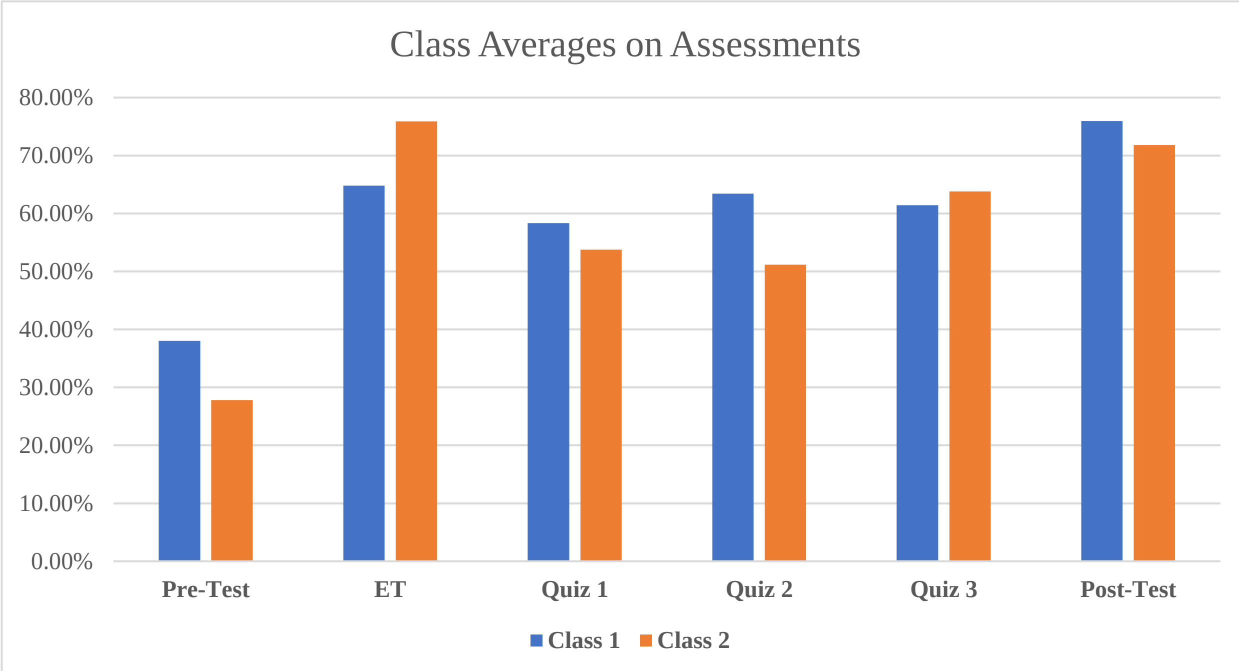
During the first day of the unit, a pre-test was provided for both classes to complete to gain some understanding about what students already know about solving systems of linear equations graphically and algebraically. All pre-tests were graded out of 12 points and were inputted into a spreadsheet. Then, for each day after the pre-test was administered, a total of 1 "exit ticket" and 3 quizzes were administered over the course of the 10-day unit (from 11/14/2022 – 12/02/2022). Prior to students being provided an "exit ticket" or quiz, students would either take notes or have opportunities to practice the skill being taught. For example, students had to practice would be doing exercises at one of the whiteboards around the room where I would check their work, completing a matching activity, and providing homework that reinforced the concepts related to each way of solving systems of linear equations. The final practice activity was a Jeopardy game that provided students with additional practice to solving systems of linear equations and inequalities. The only exit ticket was administered after the first day when discussing solving systems of equations by graphing. This exit ticket was worth 5 points. The first quiz was administered after the fourth day of the unit (November 17th). The content assessed was solving systems of equations by graphing and algebraic substitution. The second quiz was administered after learning how to solve systems of equations by elimination and applying these concepts to word problems (November 28th). For this quiz, two separate versions were created based upon student performance in the course up to that point. The third and final quiz was provided two days later and covered solving systems of linear inequalities (November 30th). All quiz scores were inputted into the same spreadsheet along with the exit ticket scores. An average score was computed for the exit ticket and for each quiz. Lastly, on the last day of the unit, December 2nd, a cumulative test was administered. Scores were inputted into the same spreadsheet and, similarly, an average score was computed. For this study, only numerical data was collected and analyzed for this study, and no other methods were used. Below is a table of the results from both classes and their performance on each assessment (denoted as Figure 1) and a bar graph comparing both class averages:

Figure 1 – Comparison of Class Averages on Assessments

	Class 1 (Control Group)	Class 2 (Experimental Group)	Avg. % Difference Class 1 v. Class 2
Pre-Test (5 pts.)	1.90 out of 5 **(38.00%)**	1.38 out of 5 **(27.80%)**	**10.20%**
Exit Ticket (5 pts.)	3.24 out of 5 **(64.80%)**	3.79 out 5 **(75.88%)**	**-11.08%**
Quiz 1 (22 pts.)	12.83 out of 22 **(58.33%)**	11.82 out of 22 **(53.74%)**	**4.59%**
Quiz 2 (30 pts.)	19.03 out of 30 **(63.42%)**	15.35 out of 30 **(51.15%)**	**12.27%**
Quiz 3 (30 pts.)	18.43 out of 30 **(61.43%)**	19.15 out of 30 **(63.82%)**	**-2.39%**
Post Test (92 pts.)	69.89 out of 92 **(75.97%)**	66.07 out of 92 **(71.82%)**	**4.15%**

Third column was calculated by subtracting the average score from Class 1 from Class 2. Negative percentages signify that Class 2 scored better, on average, than Class 1.

Figure 2 – Bar Graph Comparison



Note: 4 students were absent from each class on the day the Post-Test was administered.

Throughout the unit, I documented 4 instances when incentives were provided. The first instance occurred on the third day of the unit in which two students utilized proper mathematical vocabulary when discussing solving a system of equations by substitution. These students used phrases such as “substituting”, “solving for *x*”, “solving for *y*” and “cancelling” when discussing their process as to solving systems of linear equations. This warranted an incentive to be rewarded based upon the proper use of vocabulary. A second instance in which an incentive was rewarded was when the entire class demonstrated strong procedural fluency by completing several exercises at the board that were centered around solving systems of linear equations by all methods. Students were given candy for demonstrating competency in utilizing the correct methods to solve problems. A third instance in which an incentive was rewarded was to a group of 6 students who had completed a choice board activity relating to solving system of linear equations word problems. Students were instructed to work with a partner to answer 5 of the 9 word problems on the choice board and that students would be required to show all of their work for each problem and have their work checked by me. Out of the 3 partner pairs that showed me their work (out of 9 total pairs), these pairs demonstrated strong ability to utilize both algebraic substitution and algebraic elimination in order to solve. My final instance in which an incentive was rewarded was to the winning team in a game of Jeopardy (a total of 7 students) that centered around solving systems of linear equations. Reasons for rewarding the incentive are very similar to the previous reasons.

Data & Analysis

When analyzing the data, I noticed several trends that were of significance to determining the effectiveness of incentives as it relates to the retention and comprehension of mathematical concepts and ideas. When examining Figure 1 above, one trend that I noticed was that the average scores for each assessment for each class were in the range of 50% – 75%. This trend is quite troubling for me because throughout this unit, multiple opportunities were provided for students to ask questions if assistance was needed and sufficient time was provided to practice using the various methods. What I found even more interesting is that over the course of the unit, the experimental class (the class that was provided incentives) seemed to score, on average, significantly lower (i.e.: between 4 – 12% lower) on most of the assessments (**4** of the 6 assessments including the pre-test) provided in this unit. The most significant assessment that the experimental class scored better than the control class was the second quiz in which the class scored, on average, approximately 12% lower than the control class. Therefore, this observation provoked an important question when analyzing the data: “incentives aside, did the students truly understand the content in this unit?”. Furthermore, another question that I considered would be, “did the incentives hinder the growth of the students’ ability to comprehend and retain information?”. When considering the first question, I would believe that if students are earning, on average, between 50 – 75% of the possible points on these assessments, then I would say that there is definitely some need for improvement. While some students may tolerate performing at a level that is below my expectations for the students, I believe that any student can learn the material and apply these concepts. However, referring back to the University of California-Berkeley article, this statement contradicts the idea presented – that students have a fear of failure.

Another thought that I considered when analyzing the data was the time of day when these students were in my class. I recognize that the class periods I have selected have Algebra 1 during either 1st period (7:40 – 8:50 AM) or during 5th period (1:15 – 2:25 PM) which is the last period of the day. This made me consider whether or not students during these periods had the cognitive demand to be able to contribute to mathematical discussions and activities in a meaningful way. According to research completed at the University of Michigan in 2016, there was a diagram that displayed how between 8:00 – 9:00 AM, students’ cognitive demand decreased significantly and similarly from approximately 1:00 – 2:00 PM. Therefore, when connecting this research to this study, I believe that the times in which these assessments were provided were at times in which the students’ cognitive functions were not at their highest level. Therefore, if I were to complete this study again, I would administer these assessments during class periods in which the students have had a chance to have their cognitive functions performing at the highest level (which, according to the study, occur between 10:00 – 11:00 AM and 12:00 – 1:00 PM).

Conclusions, Implications, & Limitations

When considering the main conclusion of this study, it can be said based upon Figure 1 above that students that when students receive incentives, they will not perform as well compared to students who did not receive incentives. As shown in Figure 1, students in the experimental group performed, on average, 4 – 10% lower on assessments compared to students in the control group. Therefore, it can be stated that the students who received incentives did not retain nearly as much content and demonstrate their knowledge on the majority of assessments. A second conclusion I can make as a result of this study is how students, regardless of incentives, did not perform well in this unit. As mentioned in the analysis section of this paper, students were scoring in the range of 50 – 75% on these assessments and this tells me that the content being taught was not retained at a level I would expect given the ample amount of practice time throughout the unit. However, when I consider my conclusion of this study, there were several ideas that came to mind when considering the validity of this conclusion. First, I considered whether or not the presence of rewards provided to the students actually benefitted their ability to retain and comprehend mathematical content. I recognize that math is not every student's favorite subject, and I also recognize that a student's mathematical ability is not an innate ability, but one that is, perhaps, passed down from parent(s)/guardian(s) to the student itself. Over the course of this study, I noticed that many of my students who did not perform particularly well on my assessments had this preconceived notion that they were "bad at math". Therefore, I wonder whether or not providing these rewards did anything to change the perception of learning mathematics for those students who had the notion that math was "not for them".

One obvious implication of this study is that teachers should consider whether or not the incentives they are providing truly benefit a student's academic ability or whether the incentives provide students with an improvement in their attitude towards learning math. Even though this unit was only 10 days in length, most units that are taught at the middle school and high school level can range anywhere between 7 – 14 days (depending on the content discussed within the unit) and 10 days lies within this range. Therefore, as a future educator, I must consider whether or not the incentives I am providing will *actually* benefit a student's ability to retain and comprehend mathematical concepts.

While I recognize that there are several positive outcomes from this study, I believe that there are several limitations that have to be addressed that can possibly affect the outcome of this study if it were to be replicated. One limitation would be that the length of this study was too short. Completing a study over the course of a 10-day unit is not a long enough period to make proper conclusions. Therefore, if I were to redo this study again, or if this study were to be replicated, I would have the study last anywhere from 2 – 4 units (anywhere between 1 – 2 months) in order to obtain a better sample size. It has been proven, according to an article written Jalayer Khalilzadeh and Asli D.A. Tasci in 2017, that having a larger sample size can produce more accurate results and can show a higher statistical significance. Furthermore, over the course of the unit, I only documented 4 instances in which incentives were rewarded. I believe that if the duration of this study had increased, I believe that the number of instances would have increased significantly. I also believe that if this process of rewarding students based upon their ability to comprehend mathematical content was engrained into a daily routine, this would provide students with a clear structure as to identifying what I am looking for as the teacher in order to be rewarded.

A second limitation I recognize for this study is that only tangible rewards were used. I believe that a combination of both tangible and intangible rewards would have provided more insights into whether or not utilizing incentives does have an impact on the retention and comprehension of mathematical ideas. I believe that along with using candy as a reward, utilizing some words of encouragement and affirmation would have provided students with a second type of reward, one of which could be used to help motivate a student in order to retain and comprehend mathematical content. For example, if I were to complete this study again, I would leave direct feedback during classroom discussions by saying statements like, "I like how you used __________ (a vocabulary term or procedure) to solve this system".

A final limitation to my study was that throughout the study, students were absent from school. In particular, for the post-test, **4** of the students in the control class were absent and the same amount in the experimental class were absent. Therefore, from the control class only 19 assessments were scored and from the experimental class, only 15 were scored. As mentioned in the study completed by Khalilzadeh and Tasci in 2017, the average scores from classes where only 20/24 assessments were scored (for the control class) and 15/19 assessments were scored (for the experimental class), their respective class averages can vary widely given that the sample size was small. Therefore, if this study were to be repeated again, I would ensure that all students – no matter the class size – would take the post-test in order to obtain complete results which can lead to more accurate conclusions.

Overall, I believe that this study provided insights as to whether or not incentives truly assist students in retaining and comprehending mathematical ideas. As mentioned in the introduction, incentives have been provided to students in order to increase engagement in the classroom. However, this study ultimately led to me concluding that these incentives that reward behavior do not assist students in recalling mathematical concepts. The results of this study will allow me to consider whether or not using incentives in my classroom truly benefit my students, and I am grateful for the opportunity to engage in meaningful research that will help me run a successful mathematics classroom in the future.

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