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Honors Research Projects

The Dr. Gary B. and Pamela S. Williams Honors College

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Why We Teach Mathematics to Every Student: Determining Impact of Mathematics on Problem Solving and Logical Reasoning Skills

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Why We Teach Mathematics to Every Student

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Honors Research Project

Submitted to

The Honors College

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Dean, Honors College

Why We Teach Mathematics to Every Student:

Determining Impact of Mathematics on Problem Solving and Logical Reasoning Skills

Megan M. Harris

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Author Note

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Special thanks to Gregg Harris; my sponsor, Karen Plaster; my two readers, Dr. Wondimu Ahmed and Dr. Linda Saliga; and my advisor, Dr. Lynne Pachnowski, for giving me guidance and editing this paper.

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Abstract

The purpose of this paper is to dissect why it is important to teach mathematics to every student, even if the student does not plan on pursuing mathematics in his or her career. This paper will describe and test various reasons why mathematics is taught to every student but it will focus on math as a way to help develop and improve problem-solving and logical reasoning skills. An experiment was conducted on a random sample of fourteen University of Akron students who were measured on their problem-solving abilities and critical thinking through playing two games. These students were then compared to the other participants with regard to the level of math courses they have taken and how well they did on the games. The results show that students who have taken high level math courses, on average, were more successful (won more with less turns) in both games. This draws a correlation between taking math courses and an increase in a student's critical thinking and logical reasoning skills, skills that are important in a wide variety of careers and circumstances.

Why We Teach Mathematics to Every Student

Introduction:

The age-old question that mathematics teachers have to constantly deal with is "Why do we have to learn this? When will we ever use this in real life?" This project is inspired by those questions and by the fact that future educators, themselves, do not see why kids are forced to take math classes, like algebra, and how that would help them in the real world. In one of my classes, a future educator stated that she believed that mathematics did not need to be taught to students whose future career would not deal with the application. When the professor raised the point that you can learn other life skills from mathematics, the future educator replied that other subjects will do that well enough and that math is not needed. After this interaction, I wanted quantifiable data demonstrating the value of math to improve important life skills. This could encourage and motivate students as they can see how it would benefit and relate to themselves if they took math.

The common answer to the question why are all students forced to learn mathematics is that math can be found in everyday life; it can be seen all around us. This is partially true but people tend not to see it when it comes to higher mathematical concepts. The reason being that some of it comes naturally to them (for example what time do they have to get up in the morning so that they are ready by the time they have to leave). Students have to be taught how to gain that perspective. Another reason to study mathematics is simply for its own sake as Aristotle stated, "All human beings by nature desire to understand." People are curious beings who want to understand how and why the world works the way it does and that includes mathematics. Some students lose this feeling for numerous reasons whether it deals with failure or having other worries occupy their time. Teachers should try to reinstate this feeling as it is a great quality to have; it pushes people to improve. A way to do that is to find ways to connect their content to the interests of the kids and encourage students while maintaining high expectations. Teachers should show students that it is okay to fail as long as they keep trying to improve and grow for it will lead to a more fulfilling and worthwhile life. Another common reason given to students is that the math they are covering now will help to prepare them for college and future careers. Even though these are true they do not always work to motivate students as it is hard for them to see these applications and believe in them. This especially is true for students who are not going into STEM fields and will not see as much higher math in their future, whether it is college or their occupation. This leads to them wondering why they should even bother with higher math courses when they will not have to directly deal with those concepts. And it is a fair question that deserves a solid answer (Felton, 2014).

Other aspects that teachers rarely mention that can answer why students, including non-STEM majors, should take math courses after high school is that “mathematics emphasizes conceptual understanding, problem-solving, making connections across representations and mathematical concepts, and engaging in reasoning and argumentation” (Felton, 2014). This paper will focus on the fact that mathematics can help develop and improve problem-solving and logical and critical thinking skills. These skills are extremely beneficial as they are used by everyone and the stronger those skills are the more it can help improve life and the decisions people make. In "Critical Thinking and Emotional Intelligence," Linda Elder explains that critical thinking is "a means of assessing and upgrading our ability to judge well. It enables us to go into virtually any situation and to figure out the logic of whatever is happening in that situation." This leads to a basis for a 'rational and reasonable' emotional life. These skills and abilities lead us to live more independent lives, on average heed better results and will increase the chance of getting a job in any field. In math class, students are taught to first look at and analyze the whole problem, to think and come up with different methods and ideas on how to go about it, and then they start solving it one step at a time until they arrive at the answer. This process can be transferred to real life and leads to thinking creatively and flexibly to get the best results (Norfolk, 2003). I recommend everyone who reads this paper to also read "Why should anyone have to study mathematics?," submitted by Norfolk in 2003. You can find the link in the references. Norfolk asks the following question "Why should anyone have to study math?" to some of his University of Akron Honors students. His paper includes several of their responses and a lot of them includes the reasons I listed above but in greater detail.

Mathematics is involved and helps in each and everyone's daily lives. Aspects of our lives can be described in mathematical concepts and it helps develop mental skills including solving problems and making decisions. The reason mathematics helps develop and improve such skills is that many areas of the brain are active when students think with numbers and about formulas. Some brain functions that are involved include memory, language, attention, temporal-sequential ordering, higher-order cognition, and spatial ordering. The more people work with mathematics then the more they use and develop the parts of the brain that develops those functions mentioned above. Students use memory to recall rules, formulas, and recognize patterns; use language to understand vocabulary, instructions, and explain their thinking; and use sequential ordering to solve multi-step problems and use procedures. Also, children use spatial ordering to recognize symbols and deal with geometrics. “Higher-order cognition helps children to review alternative strategies while solving problems, to monitor their thinking, to assess the reasonableness of their answers, and to transfer and apply learned skills to new problems” (Basics of Mathematics, 2002).

Method:

To help find a relationship between mathematics and life skills like problem-solving and logical reasoning, I conducted an experiment. The experiment had a set of students play two online, single player, games that would test their problem solving and logical reasoning skills. Then there was a comparison on how they performed on the games to their highest level of math taken to see if there is a significant correlation. This experiment was approved by The University of Akron Institutional Review Board (IRB protocol # 20170911). It involved fourteen students at the University of Akron. The participants were separated into two groups. Group 1 consisted of students that did not take any math course above calculus while Group 2 consisted of students that took higher math courses, which was considered to be any math course above calculus. Calculus was the criterion that determined which participant goes in each group because calculus is typically when any additional (higher) mathematic courses become optional for students to take. It is when many people would think its content should only be taught for students who will be using it. Each participant was labeled by the highest math course they passed. The groups were separated in that manner to determine if there is a relationship between the math courses people take and their problem-solving and logical reasoning abilities. Since the participants consisted of a random sample it was assumed that the two groups were similar in all other aspects. This tended to be the case as shown by **Table 1**.

Table 1. Comparing the two sample groups

	Group 1	Group 2	Total Number from Group 1 and Group 2
Female	4	4	8
Male	3	3	6
Honors Student	1	2	3
Non-Honors student	6	5	11
1st Year Student	2	1	3
2nd Year Student	0	1	1
3rd Year Student	2	1	3
4th Year Student	0	1	1
5th Year Student	3	3	6
Total Number of Participants	7	7	14

This information was obtained by asking students to fill out a short form on general information about themselves. This form can be found in Appendix A.2. In this way, I was able to see if there were other main factors that might have played a part in how well students did on the games and to gain a better sense of what was going on in the participants' minds as they played the games. Also, I ranked the math courses on a scale of one to nine with calculus 1 ranked as a five. The higher the math course, the higher they are ranked. This part was somewhat subjective but I tried basing the rankings on the typical order students take these math courses in high school and college. The ranking for each course is marked in parenthesis in **Table 2** and **Table 3** beside the name of the highest math course the participant had taken. A ranking is included in the data so that the correlation between the highest math course taken and the success in the games could be calculated.

After they signed the consent form (Appendix A.1), each participant then was directed to the games, which included *Pet Detective* (Pet Detective, 2013). The goal of the game is to get the various types of pets back home with the amount of gas given each round, taking the shortest route possible. This involves planning, specifically trip planning, which is a real-life application of problem-solving and consists of thinking ahead, evaluating options, and choosing the best course of action. Each participant was given fifteen minutes to play this game. The game is broken into levels, with three rounds in each level, where the task gets more challenging the higher the level. Participants were instructed that they were not allowed to move onto the next level until they passed all three rounds in the level. They were measured by how many levels they were able to solve in the given amount of time and how many rounds (out of the three) they were able to successfully pass in each level. If they failed a round, they still play all three rounds to finish out the level. That way, the total amount of rounds they played and the total amount of rounds they passed could be measured. This led to calculating a “Success Rate” (the number of rounds passed divided by total amount of rounds played), meaning how often the participant passed a round in the fifteen minutes they played. Both the levels and the rounds passed were measured. The level represents the difficulty of the game the participants reached. The amount of rounds played can greatly differ as participants play the game at different rates and could replay a level multiple times. Those factors would not be represented if only the level they reached was recorded. **Table 2** shows the results from *Pet Detective.*

The other game that each participant played on the computer is called *Mastermind* (Play Mastermind Online, n.d.). The goal of the game is to figure out the color sequence in ten guesses or less or they lose. After each guess, there is a hint of how many of the colored balls were the right color and/or in the right position. The participant will use those hints to help calculate and deduce their next guess. In this game, the participant will use logic and deductive reasoning skills. Each participant played this game five times so that an average could be calculated to help get the best representation for each participant. This game is measured by how many of the sequences the participants were able to successfully get right out of the five times they played, along with the number of guesses it took them to come up with the right sequence, and the time it took them to complete the five games . The results are displayed in **Table 3.**

Data and Graphs

Table 2. Recorded data from *Pet Detective* and calculated success rate and averages

Participant #- Highest Math Course Take	Levels Passed	Rounds Played	Rounds Passed	Success Rate
Group 1				
1- Geometry (3)	3	26	20	77%
2- Pre-Calculus (4)	3	16	13	81%
3- Statistics (2)	4	24	19	79%
4- College Algebra (1)	5	36	24	67%
5-Pre-Calculus (4)	6	35	25	71%
6- Statistics (2)	3	36	27	75%
7- Pre-Calculus (4)	4	29	22	76%
Averages for Group 1	**4**	**28.86**	**21.43**	**75%**
Group 2				
8- Calculus 3 (7)	4	33	26	79%
9- Calculus 2 (6)	4	21	18	86%
10- Calculus 2 (6)	5	21	19	90%
11- Calculus 2 (6)	4	27	22	81%
12- Differential Equations (8)	7	24	23	96%
13-Abstract Algebra (9)	5	27	22	81%
14- Differential Equations (8)	4	20	18	90%
Averages for Group 2	**4.71**	**24.71**	**21.14**	**86%**

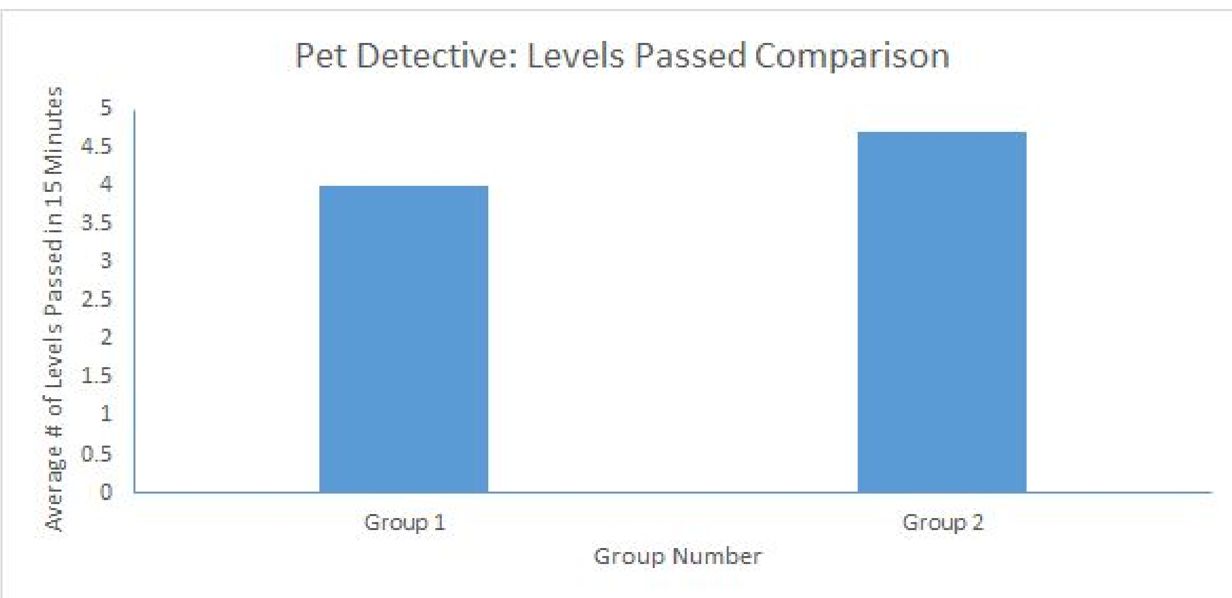

Figure 1. Bar graph comparing the average number of levels passed in *Pet Detective*

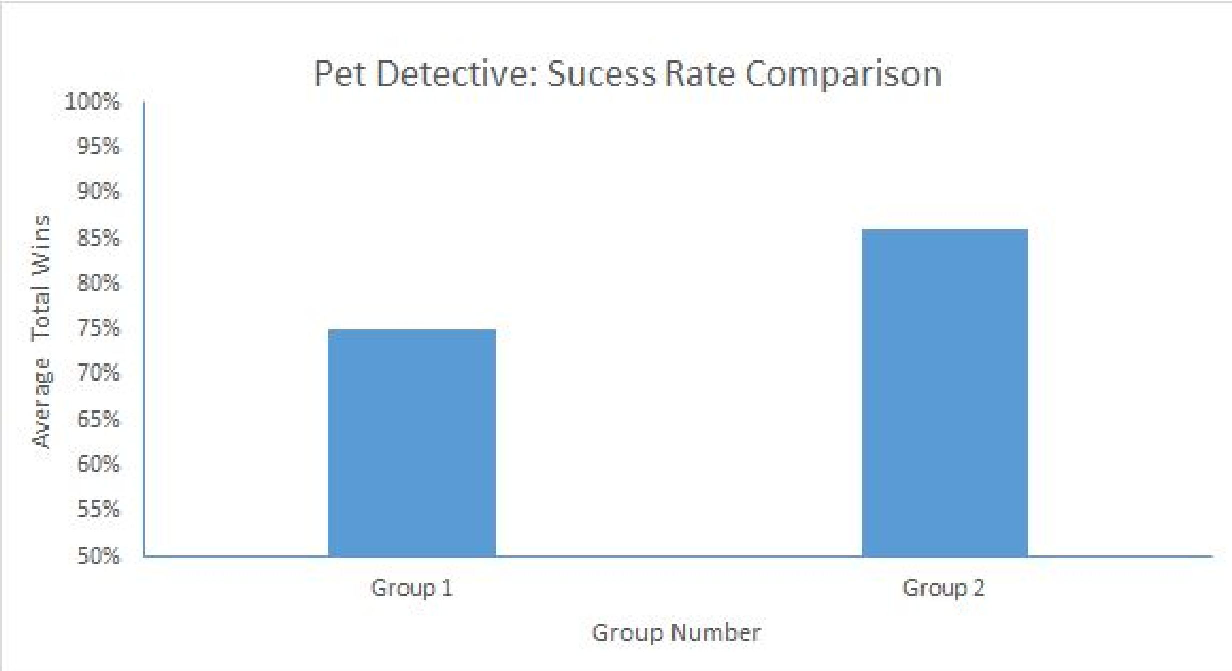

Figure 2. Bar graph comparing the average success rate from *Pet Detective* between the 2 groups

Table 3. Recorded data from *Mastermind* and calculated average of wins, turns, and time

	Game 1		Game 2		Game 3		Game 4		Game 5		Total Wins	Total Turns	Total Time (Minutes:Seconds)
Participant # - Highest Math Course Take	Pass?	Turns	Pass?	Turns	Pass?	Turns	Pass?	Turns	Pass?	Turns			
Group 1													
1- Geometry (3)	Yes	7	No	10+	Yes	8	No	10+	No	10+	2	45	17:14
2- Pre-Calculus (4)	No	10+	No	10+	Yes	9	Yes	9	No	10+	2	48	13:53
3-Statistics (2)	No	10+	No	10+	No	10+	No	10+	Yes	7	1	47	39:20
4- College Algebra (1)	No	10+	No	10+	Yes	8	Yes	6	Yes	9	3	43	15:26
5-Pre-Calculus (4)	No	10+	Yes	8	Yes	5	Yes	9	Yes	6	4	38	17:38
6- Statistics (2)	No	10+	No	10+	No	10+	No	10+	Yes	8	1	48	19:32
7- Pre-Calculus (4)	Yes	9	No	10+	Yes	7	Yes	7	Yes	6	4	39	19:34
Averages for Group 1											**2.43**	**44**	**20:22**
Group 2													
8- Calculus 3 (7)	Yes	10	Yes	8	Yes	8	Yes	10	Yes	5	5	41	15:36
9- Calculus 2 (6)	Yes	8	Yes	7	Yes	7	Yes	8	No	10+	4	40	12:01
10- Calculus 2 (6)	No	10+	No	10+	No	10+	Yes	9	Yes	6	2	45	14:22
11- Calculus 2 (6)	No	10+	Yes	7	No	10+	No	10+	Yes	5	2	42	15:06
12- Differential Equations (8)	Yes	5	Yes	6	Yes	5	Yes	5	Yes	8	5	29	18:07
13-Abstract Algebra (9)	Yes	7	Yes	7	Yes	9	Yes	7	No	10+	4	40	15:12
14- Differential Equations (8)	Yes	10	Yes	7	Yes	7	Yes	5	Yes	6	5	35	17:02
Averages for Group 2											**3.86**	**38.86**	**15:21**

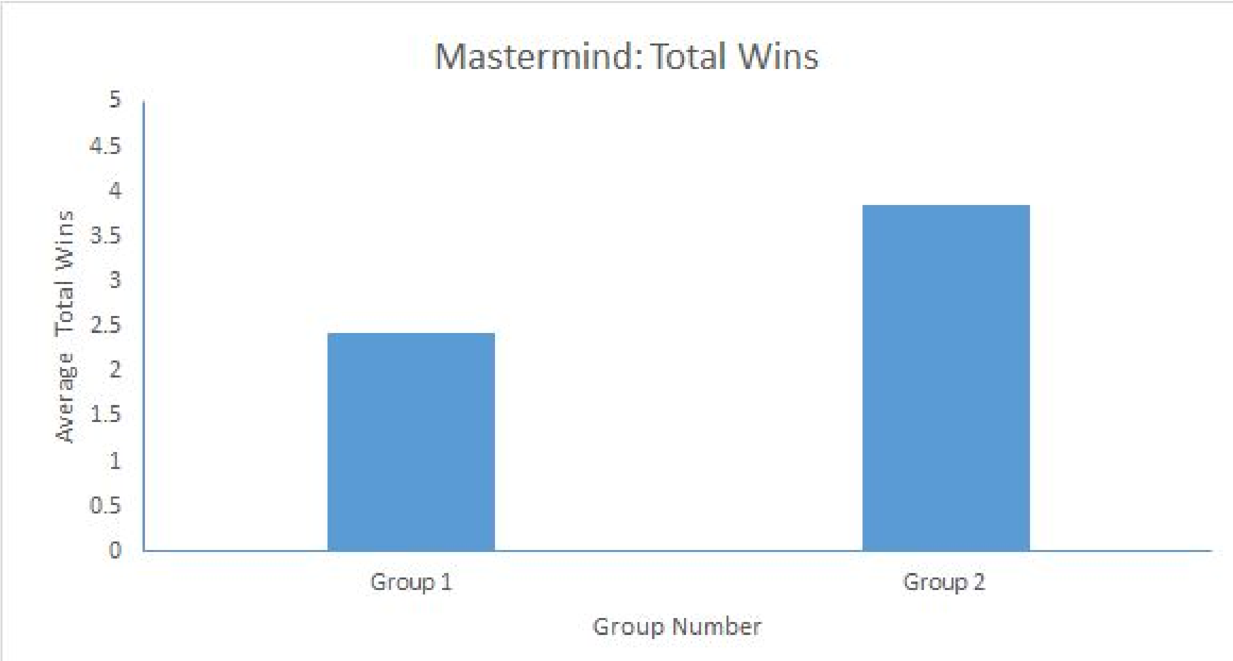

Figure 3. Bar graph comparing the average total wins between the two groups from *Mastermind*

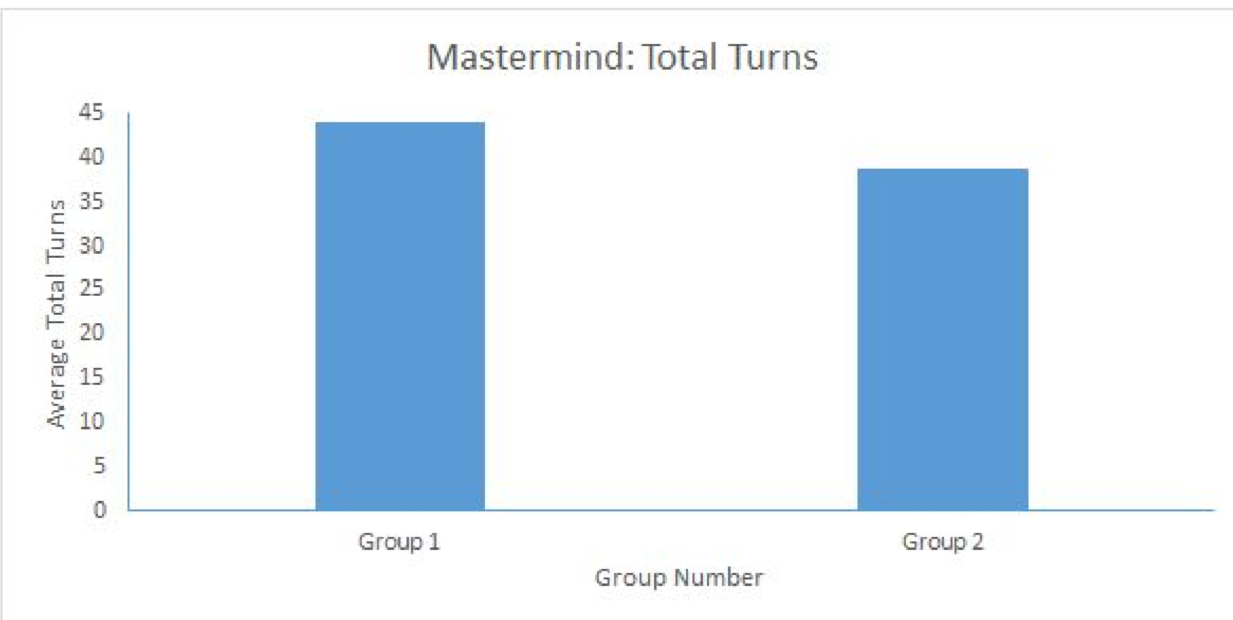

Figure 4. Bar graph comparing the average total turns between the two groups from *Mastermind*

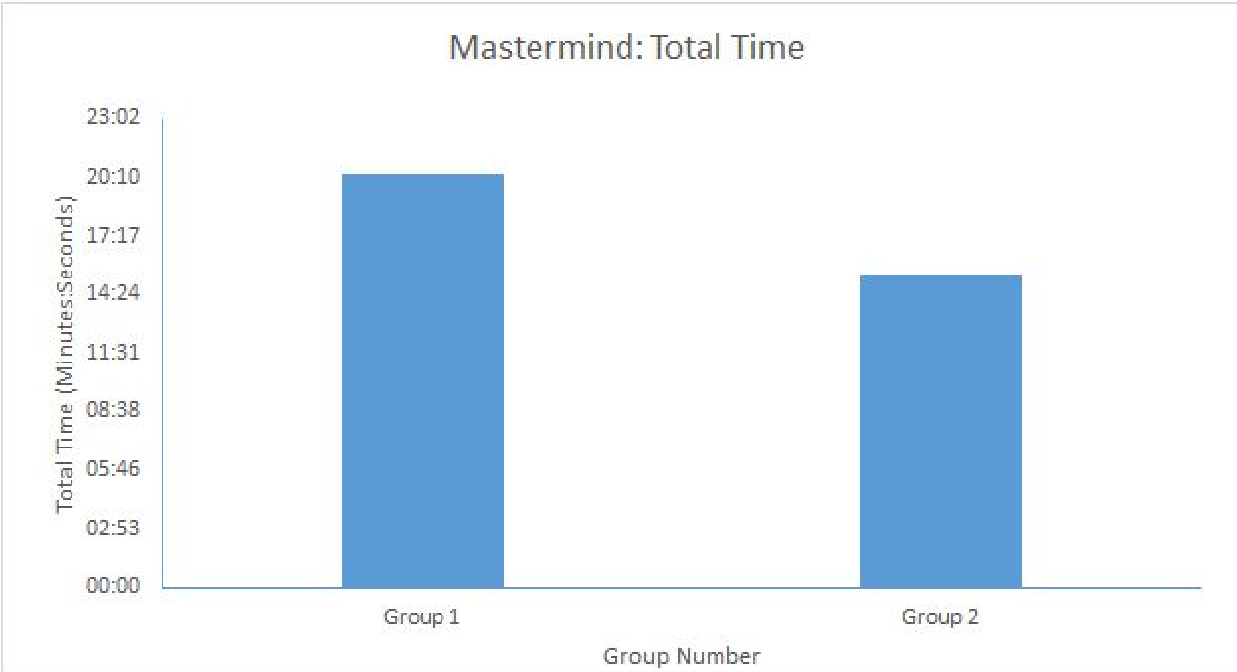

Figure 5. Bar graph comparing the average total time between the two groups from *Mastermind*

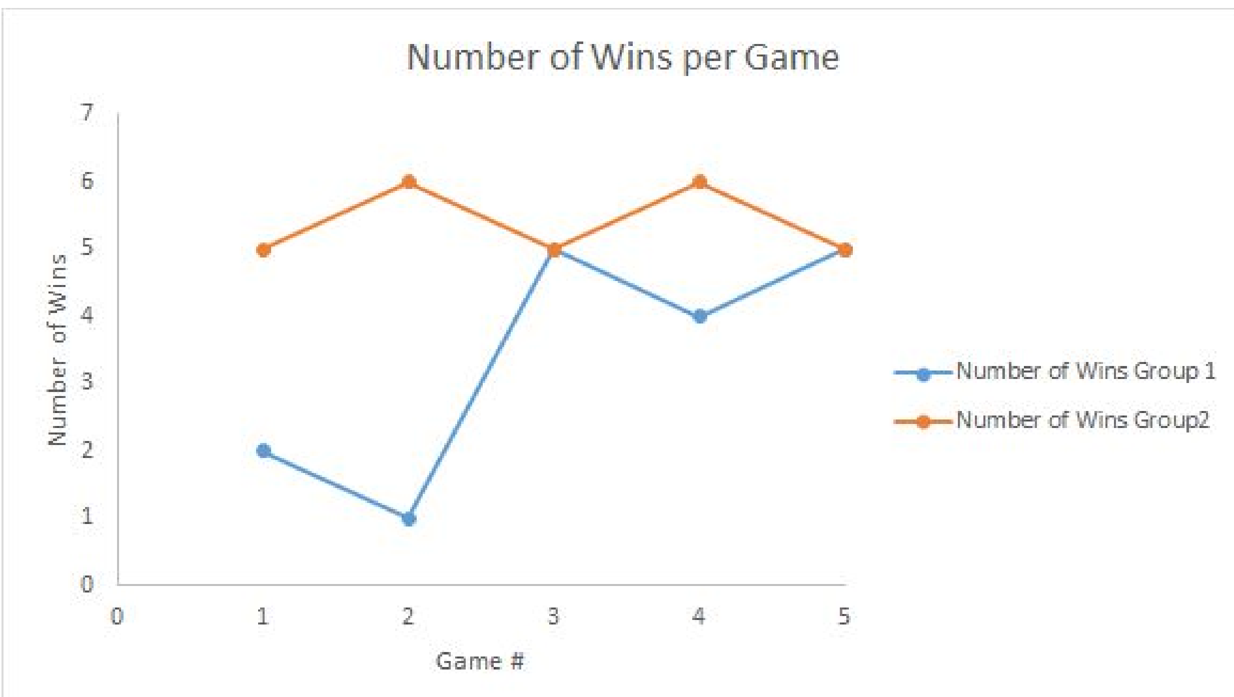

Figure 6. Line graph comparing the number of wins per game from *Mastermind*

Calculations and Results

The results from *Pet Detective* can be found in **Table 2** are not that spread out. They do not have a large variation between participants, this may be due to the fact that there was a time constraint on the game of only fifteen minutes. But, from the results, Group 2, on average, passed more levels and had a higher success rate as shown in **Figure 1** and **Figure 2**. The Pearson r correlation scale is from -1 to +1 with the positive number representing that as the independent variable increases the dependent variable also increases while the negative number represents that as the independent variable increase the dependent variable decreases. Generally, comparisons are considered to have a strong positive correlation when a correlation is equal to or greater than 0.5 and a strong negative correlation when the correlation is equal to or less than -0.5 (Wilson, 2009). The correlation between the math course taken and levels passed was only 0.37. This means that there is a moderate correlation that the higher the math course a student takes the more levels they passed. This might be due to the time constraint and if there was more time there might have been a larger gap. However, the correlation between the math course and the success rate was 0.73. That means there is a strong correlation that the higher the math course a student takes the higher their success rate is. In other words, Group 2 more often passed their rounds than Group 1.

I used software called *Statcrunch* to analyze the collected data and conduct a two-sample t-test without pooled variances (StatCrunch, 2017). This measures if the data is statistically different. This is done by making a null hypothesis, a hypothesis that assumes there is no significant difference between specified samples. The null hypothesis was that Group 1 and Group 2 should, on average, have the same scores. Statistically, if a null hypothesis has less than five percent chance of occurring from the collected data the hypothesis can typically be rejected. However, results can contain type I (false positive where the null hypothesis was rejected when the results that occurred is not generally the case) or type II (false negative where the null hypothesis could not be rejected when the results that occurred is not generally the case) errors. Tus, in this case, the experiment should be repeated and contain a larger sample size (Lane, n.d.). There were no significant findings with the groups and levels passed and, therefore, no foundation to reject the null hypothesis. There was a 13.07 percent chance of the results occurring (these results can be found in Appendix B.1), assuming the hypothesis was true, which is not rare enough to completely reject the hypothesis. This does not mean that the hypothesis is true only that the results were inconclusive. However, there were significant findings on the groups with regard to the success rate of passing rounds in *Pet Detective*. There was only a 0.16 percent chance that the results could have occurred if the hypothesis was assumed to be true (these results can be located in Appendix B.2). It can be then concluded that, on average, students from Group 2 statistically had better success rates than group one. From these results, it can be concluded that Group 2 was generally better and more efficient in planning the route to get the various pets home. Thus, it may also be suggested that the participants in Group 2 are better at evaluating options, choosing the path that is more likely to produce the best results, and at problem-solving.

The results from *Mastermind* show that Group 2, the group that took higher and more math courses on average, won the game more often, in fewer turns, and in less time as shown by **Figure 3**, **Figure 4**, and **Figure 5** in that respective order. In fact, Group 1 won the game, on average, only 48.6% of the time while Group 2 won the game 77.2% of the time. That means Group 2 was more than 1.5 times more likely to win than Group 1. **Figure 6** shows the total number of wins from each group for each game. And it can be seen that Group 2 was consistent throughout the five games, where five or six of the participants won every game while Group 1's wins increased the more they played. Both Group 1 and Group 2 had similar amount of wins by game 3. This can suggest that Group 2 was quicker at analyzing the game and solving the problem but with practice and repetition anyone can succeed. Also, Group 2, on average, used five fewer turns when playing this game meaning they needed fewer rounds to come up with the correct sequence. Notice in **Table 3**, under the "Turns" columns there are several "10+" that represents that the participant would have needed more than ten guesses if they were able to play the game pass that amount of turns. When calculating the average amount of turns used, the number ten was used in place of 10+. The results would have been more accurate and better if the participants were able to continue the game beyond ten turns to see how many turns and how much time it would have actually taken them to complete the game. However, the data still gives us a fairly good idea how well the participants did. The correlation between the math course taken and the number of wins was 0.67 while the correlation between the math course taken and the total numbers of turns used in the five games was -0.64. Therefore, it can be concluded that there is a strong correlation between the higher the math course students take and the number of wins on *Mastermind* and the fewer turns they used when playing.

The same null hypothesis that was used for *Pet Detective* (that Group 1 and Group 2 on average have the same results) was used for *Mastermind* when calculating the two-sample T hypothesis test. When comparing the data involving the number of wins from each group, the test shows there is only 3.2 percent chance of the results actually occurring as they did if the null hypothesis was correct, meaning it would be extremely rare. The results given by the two- sample T hypothesis test can be found in Appendix B.3. This allows us to conclude that the findings are statistically significant to state that, on average, Group 2 is more likely to win than Group 1. In addition, using the data collected on the number of turns each participant took, the two-sample T hypothesis test (can be found in Appendix B.4) states that there is only 3.35 percent chance of the results to occur the way they did. Since that is less than 5 percent, it can be considered significant findings and can be concluded that Group 2, students who take higher and more math courses, are likely to use fewer turns than students in Group 1. These conclusions are significant as it allows the data not only be applied to the sample groups but can be generalized to the population. Also, when asked what strategy they used to play *Mastermind* people from Group 2 were overall better able to write and describe their method of playing. Group 1 struggled more with trying to describe their thought process throughout the game, where some students put “I don’t know”, “I just randomly guessed”, and “N/A”. From these results, it can be suggested that students from Group 2 were better able to deduce what colors and position the balls were in and had a better grasp of what they were thinking. This implies that students in Group 2 have better logical reasoning skills.

Conclusion

If this experiment was to be repeated again, it should use a bigger sample size to get a better representation. But from the results of these two games, this study shows some kind of correlation between the level of math course and problem-solving and logical reasoning skills. A conclusion cannot be made saying that the higher the math courses students take the more superior their problem-solving and logical reasoning abilities are compared to others as there are too many other factors that could contribute to why some people did better on the games than others. One factor could be that students who took higher and more math courses chose to take them because they showed a natural aptitude in problem solving. This can be tested if the experiment was to be repeated where there is a third group of students who plan to take math classes above calculus but have yet to do so. But, it can be concluded that there is a connection or relationship between the level of math taken and higher ability in problem-solving and critical thinking. Upperclassman in Group 1 had more experience in their field but yet they did not do as well as underclassmen students that took higher math courses. This suggests that other subjects don't give the same results as math courses do with the type of skills mentioned above. If this experiment was to be repeated, Group 1 should consist of participants that all have primarily studied and focused on the same subject, thus narrowing down the majors included in Group 1. This way the comparison is more of a head to head and it can be shown which subject truly helps most in developing certain life skills.

Galileo once said, “Mathematics is the language in which God has written the universe.” Mathematics is all around us and it is the mathematical concepts that provide us with answers to how our world is able to work or function the way it does. Understanding these concepts can help us better understand and gain a grasp on our world that we live in that has so much uncertainty to it. The conclusion that taking mathematics can help develop and improve skills along the lines of problem-solving and logical reasoning (along with the other reasons listed at the beginning of the paper) is important and can be extremely beneficial to know. This can encourage and motivate students in math settings for it relates math to the students' lives and shows them why it is beneficial for them to learn. Some students are better at math than others but every person is capable of learning and growing in mathematics and the skills associated with it. People who turn away from mathematics, who hate it, and will try to avoid it in the future are the ones who got frustrated, gave up, and tend to think that they couldn't learn the concepts that math just was not for them. It is that kind of thinking that makes that statement true and will lead them coming up with excuses why math is not important and think it is a waste of their time. This can cause those students to miss out on all the benefits that mathematics can offer. This is why it is so important for teachers, parents, or anybody to help students realize that learning mathematical concepts and how to apply it would be beneficial for them and lead to a more successful life. The goal should be to lead as many people to success as we can since it should increase the level of happiness and create a better world in the future.

Appendix A: Forms Filled Out by Participants

1. Informed Consent Form

The University of Akron
Consent Form

Title of Study: Why We Teach Mathematics to Every Student

Introduction: You are invited to participate, along with fourteen others, in a research project being conducted by Megan Harris and Karen Plaster in the Department of Education, at The University of Akron.

Purpose: This study is to measure and assess your problem solving abilities and logical reasoning. These results will then be compared to other people with different majors.

Procedures: You will play two online- games on a surface pro. One game is called "Mastermind" and it's where you have to try and figure out a computer's sequence. You will play this game five times. The second game called "Pet Detective" involves getting pets back home with the amount of gas given each round. You will be given fifteen minutes to play this game. Specific instructions will be given when you begin playing. After you play the two games then you just have to fill out a short form about your experience. Your participation should only take thirty minutes to an hour tops.

Exclusion: "Mastermind" involves figuring out a sequence with different colors so if you are colorblind you should not participate in this study as it may affect results. Also, if you have ever heard of or played either "Mastermind" or Pet Detective" you shouldn't participate as you would be at an advantage compared to other participants.

Risks and Discomforts: There are no known risks to your participation in this study other than possible stress or anxiety that might come from playing games. Should any more information on such risks become known it will be communicated to you as quickly as possible.

Benefits: You will receive no direct benefit from your participation in this study, but your participation may help us better understand how taking different subjects affects our thinking and reasoning.

Right to refuse or withdraw: Your participation in this study is voluntary. You are free to discontinue participation in this study at anytime. Your refusal to participate or if you decide to withdraw from the study at any time will involve no penalty.

Anonymous and Confidential Data Collection: Any identifying information collected will be kept in a secure location and only the researchers will have access to the data. Participants will not be individually identified in any publication or presentation of the research results. Only aggregate data will be used. Your signed consent form will be kept separate from your data, and nobody will be able to link your responses to you.

Confidentiality of records: The form that will be given to you after you play the two online-games will not ask for your name, email ,address, or phone number. Your participation will be kept anonymous. However, I will record the computer screen as you are playing. This way I can better measure data without having to interrupt you or watching over your shoulder. This recording will not show either your face or have any audio. The only thing it will be recording is what you're doing on the screen. From that recording I will gather data and compare it to other participants. That data will then be used in my honors research project paper.

Who to contact with questions: If you have any questions about this study, you may call Megan Harris at (330)704-2508 or Karen Plaster at (330)972-6906. This project has been reviewed and approved by The University of Akron Institutional Review Board. If you have any questions about your rights as a research participant, you may call the IRB at (330) 972-7666.

Acceptance & signature: I have read the information provided above and all of my questions have been answered. I voluntarily agree to participate in this study. I will receive a copy of this consent form for my information.

Participant Signature **Date**

____________________________________ _______________________

2. Form to Gain General Information about Participant

Please indicate your:

Age: ______________________ Gender: ______________________________

Year or Grade level: ____________ Major: ______________________________

Please answer the following questions:

(1) Are you color blind? ______

(2) Have you ever heard or play the games "Master Mind" or "Pet Detective" before today? ____

(3) What was the last math course you have taken? ___________________

What semester/ year? ___________

(4) What has been the highest math course you have taken? _______________

(5) Are you part of the Honors College at The University of Akron? _____________

What was your method for playing "Master Mind"?

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____

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What was your method for playing "Pet Detective" ?

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Appendix B: Data Calculations

1. Software Calculations comparing the number of levels passed in *Pet Detective* between the two sample groups using *StatCrunch.* Information under "Two sample T hypothesis Test" states the variables and hypotheses being tested. Information under "Hypothesis test results" includes the measurements that are taken during the test. The P-value is the measurement that is used in the paper and is the probability that the null hypothesis is true.

Two sample T hypothesis test:
μ_1: Mean of Group 1 Levels Passed
μ_2: Mean of Group 2 Levels Passed
$\mu_1 - \mu_2$: Difference between two means
H_0: $\mu_1 - \mu_2 = 0$
H_A: $\mu_1 - \mu_2 < 0$
(without pooled variances)

Hypothesis test results:

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
$\mu_1 - \mu_2$	-0.71428571	0.60609153	11.983562	-1.1785113	0.1307

2. Software Calculations comparing the "Success Rate" from playing *Pet Detective* between the two sample groups using *StatCrunch.*

Two sample T hypothesis test:
μ_1: Mean of Group 1 Success Rate
μ_2: Mean of Group 2 Success Rate
$\mu_1 - \mu_2$: Difference between two means
H_0: $\mu_1 - \mu_2 = 0$
H_A: $\mu_1 - \mu_2 < 0$
(without pooled variances)

Hypothesis test results:

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
$\mu_1 - \mu_2$	-11	2.9589022	11.263921	-3.717595	0.0016

3. Software Calculations comparing the number of wins from playing *Mastermind* between the two sample groups using *StatCrunch.*

Two sample T hypothesis test:
μ_1: Mean of Group 1 Wins
μ_2: Mean of Group 2 Wins
$\mu_1 - \mu_2$: Difference between two means
H_0: $\mu_1 - \mu_2 = 0$
H_A: $\mu_1 - \mu_2 < 0$
(without pooled variances)

Hypothesis test results:

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
$\mu_1 - \mu_2$	-1.4285714	0.69985421	11.963077	-2.0412415	0.032

4. Software Calculations comparing the total number of turns it took the participants to complete the five game in *Mastermind* between the two sample groups using *StatCrunch.*

Two sample T hypothesis test:
μ_1: Mean of Group 1 Turns
μ_2: Mean of Group 2 Turns
$\mu_1 - \mu_2$: Difference between two means
H_0: $\mu_1 - \mu_2 = 0$
H_A: $\mu_1 - \mu_2 > 0$
(without pooled variances)

Hypothesis test results:

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
$\mu_1 - \mu_2$	5.1428571	2.5394841	11.386762	2.0251582	0.0335

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