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Exploration of the factors of mathematics anxiety and its impact on the achievement of students in mathematics: A systematic review

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Abstract--Mathematics is considered to be an important discipline and every student globally is bound to learn mathematics in curriculum for better opportunities in future and leading a successful life. Basic math skills are important for success in school and everyday life. Yet many people experience uneasiness and fear when dealing with numerical data, often regarded as math anxiety but Math anxiety is not limited to a minority of individuals nor to one country.

International comparisons of high school students show that some students in every country are anxious about math. A review of various research papers is presented in this article for exploring the factors of math anxiety among students and how math anxiety has affected the achievement among students in the subject of mathematics.

Keywords---mathematics anxiety, students, basic math skills.

Introduction

Mathematics is a fundamental part of human thought and logic, and integral to attempts at understanding the world and ourselves. Mathematics provides an effective way of building mental discipline and encourages logical reasoning and mental rigor. In addition, mathematical knowledge plays a crucial role in understanding the contents of other school subjects such as science, social studies, and even music and art. The whole world is around mathematics and it is essential to teach mathematics as a school subject. It is a fundamental science where students are nurtured in the school environment for further development and implementation in day-to-day life. Many factors can lead to math anxiety, which include student-related factors, teacher and parents, environment, social, cognitive, curriculum, and academic factors, and time. A theory explaining the cognitive aspects of math anxiety suggests that individuals suffering from math anxiety don't necessarily suffer from math learning disabilities ([Ashcraft and Kirk, 2001](#); [Ashcraft et al., 2007](#)). All these factors show equal impact which can cause math anxiety. Even when the student doesn't perform well, can lead to math anxiety. Teachers and parents can influence the students indirectly which eventually shows math anxiety. Environment means the negative classroom experiences can open to math anxiety. The effect of parental anxiety on their child's anxiety is mostly seen in mother and child pairs ([Casad et al., 2015](#); [Maloney et al., 2015](#); [Daches Cohen and Rubinsten, 2017](#)). The cognitive factor says that when students don't have high math ability can pave the way to math anxiety.

Math anxiety is a learned experience. It can be unlearned and replaced with positive responses. A positive experience when learning mathematics can change these feelings and future success in mathematics can be achieved. A child feels that he is the only one who doesn't get that. He will be panicked when he is asked to solve a math problem. He starts to avoid math. He feels guilty that he is not able to do the activity. He will not be able to concentrate or focus on the sum. Unfortunately, the curriculum can also be a factor that can accompany math anxiety. A huge curriculum, where the student can't cope with the flow along with the other students may also lead to math anxiety. Schunk's (1981, 1982a, 1982b) work with elementary school children has shown the importance of self-efficacy as a factor in children's math performance. Some researchers find that math self-efficacy is a great predictor of math anxiety. This makes the students feel that he is the only one in the class who is unable to understand the concept. Teachers and parents who don't have a positive attitude toward math, can't encourage their children to continue their struggle to achieve. When the teacher can't implement effective strategies in the teaching-learning process, then there will a lack of

understanding of the concept. Bandura (1997) provides evidence that self-efficacious students participate more readily, persist longer, work harder, and have fewer emotional reactions (all behavioral factors) when they encounter difficulties than do those who doubt their capabilities and strengths. When parents compare their children with other students then they will feel pressurized that even they have to try harder to get an appreciation from their parents. When the students seek the help of their parents for completing their homework, then the students feel very discouraged to proceed further.

Mathematics anxiety is a crucial factor that makes students move away from mathematics. Many factors will affect the level of math anxiety in the students. It may depend on the student itself, sometimes the teachers, parents, the environment, and even cognitive factors. A heavy curriculum can also be a factor that might lead to math anxiety. The current curriculum of math is not providing a conceptual understanding of math, instead, it focuses on teaching them to by heart formulas and methods. Because of that children will forget them soon and undergo frustration. This research study helps to find the factors that affect math anxiety and how does math anxiety influences mathematics achievement. Different factors affect math anxiety and in turn, affect mathematics achievement. Some of the research papers suggest that math anxiety and mathematics achievement are interrelated with each other. Because of math anxiety, math performance will be lowered and because of poor math performance, may lead to math anxiety.

A study has been done on each objective in detail with the reference of sufficient number of relevant research papers from the field of mathematics anxiety. Willis (2010) described that the emotional reactions of math anxiety like fear can shut down the working memory that is needed to learn and solve problems. She concludes that when the child is stressed, then he can't let his brain think. When the classroom is very crowded, then the teacher can't focus on every student, which is not possible in a crowded classroom. Some students might not be interested to listen in class or lack of concentration can lead to math anxiety. An additional factor can be Time. Whenever a student comes to know that he will be having a test someday, this delay will cause fear to set in. He knows that he can't avoid it, so he starts to panic. The student combines the fear of not being confident enough to give the test, the uncertainty of being able to do the problems, and the urgency to complete everything on time which all together develops into math anxiety. When teachers bully them in front of the class, it may cause anxiety and become downhearted. Geist (2010) believes the math curriculum used in school contributes to math difficulties. Because of the hectic schedule, the students will neglect the fact that why they have to learn math.

When the students complain that they are not understanding anything, but the teachers are not ready to give an ear to them, that eventually leads to math anxiety. The common thing that every teacher does is that they teach students one model of a sum but give another kind of model. Teachers think that students can do that, but the irony is that students are not able to do the other model sums. The students are expected to understand the problem after explaining it for the first time. Sometimes, the teacher exhibits anger when the students ask for extra help. Furner and Duffy (2002) propose that learning from their mistakes

and asking questions can help a child overcome his math anxiety and they suggest that this will be the correct environment for the students to learn.

According to Deficit theory, (Hembree, 1990; Tobias, 1986), low academic abilities may cause a high level of math anxiety. It can be caused by the previous negative experience with mathematics. This happens when the child is suffering developmental problems from childhood. The Theory of Cognitive Interference suggests that a high level of math anxiety might result in unsuccessful problem-solving. Math anxiety and math performance can cause and affect each other. Math anxiety affects the working memory of the brain which helps in problem-solving. Negative classroom experiences can lead to avoidance of mathematics. A long-term effect of math anxiety is that they will be avoiding mathematics to a great extent. According to this theory math anxiety mediated by working memory, interferes with the ability to solve math problems, which results in low math achievement or avoidance of math content (Ashcraft & Krause, 2007; Morsanyi et al., 2014).

Math anxiety affects the effectiveness of performance. Even simple arithmetic is so problematic for students with math anxiety. Some of the researchers suggested that not all students who are suffering from math anxiety will not be able to do math and control of negative emotions can help them to overcome math anxiety. The deficit of math anxiety might be due to math ability differences rather than math anxiety itself. It has been suggested that math anxiety affects math performance straining working memory (Ashcraft & Kirk, 2001) as well as a long-term effect, which leads to the avoidance of situations involving mathematics. Most of the studies suggest that, if the elementary education was good enough then the student will be away from math anxiety since it is considered the building block. Math anxiety leads to avoidance of math because it disrupts the working memory resources that students use to solve difficult problems at the moment. Unfortunately, math anxiety creates negative thoughts which ruin the efficiency of the working memory. Lyons and Beilock (2012) have explored that not every student with math anxiety will perform poorly in math and suggested that control of negative emotional responses may help them to overcome the math anxiety.

Highly math-anxious students perform poorly in mathematics. Math anxiety leads to less motivation for mathematics. The worries and tension from math anxiety occupy the cognitive resources and divert the attention that could be otherwise used for the task. Working memory is a chief cognitive construct involved in maintaining relevant information in a highly active state and inhibiting interfering information (Engle, 2002). In addition to impeding task performance by draining working memory and distracting task focus, mathematics anxiety might also cause a negative emotional experience, which potentially could cause more anxiety in the future, and result in task avoidance motivation, negative attitudes toward self-perceptions of competence, and lower confidence in mathematics competence. In early research, they found that math anxiety had very little effect on simple arithmetic in high school students because of memory retrieval (Ashcraft & Faust, 1994). But in more complex arithmetic problems they showed either slow performance or less accurate performance.

Many studies suggest that math anxiety is more in female students than male students. It is suggested that mathematics anxiety may impact math performance over time. The link between math anxiety and math performance may show a negative impact on younger adults and might be less in elementary students. But some other studies suggest that math anxiety can develop at any time of life. Although there is evidence that there is a negative relation between math anxiety and math performance, the directionality of this relationship is unclear. The relation between math anxiety and math performance is likely bidirectional. High math anxiety not only impairs math performance but also leads to lower motivation in mathematics, higher mathematics avoidance, less effort, and persistence in mathematical problem solving, and less likely to take math-oriented courses in further studies (Ashcraft and Krause, 2007).

Math anxiety is believed to cause negative thoughts and ruminations, often about the failure in the math task (Ashcraft & Kirk, 2001). Thus, high math-anxious students engage with mathematics tasks they try to do two things at once: (a) dealing with the negative thoughts and ruminations and (b) trying to do the math problem. High math-anxious students are slower and make more errors even during basic arithmetic problems. Low math-anxious students showed this efficiency with increased activation. High math-anxious students can't perform numerical problems such as imagining what a 3D object looks like when it is rotated (Ferguson, et. al., 2015). The reduced competency of the student leads to disfluent learning and performance which leads to math anxiety. Students who have reduced math abilities avoid taking math classes and ignore math homework which makes them further behind in their math understanding and leads to math anxiety. Hence, the study intended to achieve the following objectives of the study.

1. To explore the factors of mathematics anxiety among students.
2. To find out the effect of mathematics anxiety on the achievement of students in mathematics.

To achieve the objectives of the present study it was decided by the investigators/researchers to review various research and review papers available online on different databases. Ten to fifteen research papers were reviewed in context to each objective. The data was collected from online databases like Elsevier, Google Scholar, and Science direct. Every research paper that is related to the objectives of this review is individually studied thoroughly. There are two objectives and investigators have studied sufficient research papers to find out the factors of Mathematics anxiety and their effect on Mathematics performance. The other objective was also studied in the same way as the previous one. As of objective one, all the factors that affect math anxiety were combined. And for objective two, the effects of math anxiety on mathematics achievement among students were also combined. Later, finally, objectives one and two were combined to form an entire summary of the two objectives.

Systematic Review of Research Studies

After systematic review of the research articles, the following factors of mathematics anxiety among students were explored by the investigators.

Student related factors

According to Dowker et al. (2016), it is reasonable to assume that no genetic factors that influence math anxiety. But in a multivariate analysis (Wang et al., 2014) math anxiety was impacted by genetic and non-familial environmental risk factors, and genetic factors were correlated with math-based problem-solving. While performing a math task, there is the activation of negative emotions like fear, anxiety, or getting panicked was observed in high-math anxious students. This shows an effect on cognitive control function (Rubinsten, et. al., 2018). Mehmet and Hulya (2021) assume that the student-related factors that cause math anxiety are -

- (a) Lack of knowledge of students from the lower classes.
- (b) Dyscalculia.
- (c) Not understanding the logic of the problem.
- (d) Failure to grasp the importance of mathematics in daily life.
- (e) Afraid to answer a question wrong.
- (f) Being bored.
- (g) Afraid of reading long sentence problems.
- (h) Lack of concentration.

Environmental Factors

Math anxious parents can trigger or intensify their child's anxiety when involved in helping with their math homework. The effect of parental anxiety on their child's anxiety is mostly seen in mother and child pairs (Casad et al., 2015; Maloney et al., 2015; Daches Cohen and Rubinsten, 2017). Negative pedagogical experiences may also lead to math anxiety. According to many studies, math anxiety was reduced when using teaching methods that will create interest in math. Mehmet and Hulya (2021) assume that **other factors** that cause math anxiety are

- (a) Huge size of the curriculum.
- (b) Crowded classrooms.
- (c) Insufficient course materials.
- (d) Inappropriate evaluation system.

Parents and Teachers as factors

Mehmet and Hulya (2021) also assumed that teacher-related factors that cause math anxiety are

- (a) Insufficient knowledge of effective teaching strategies.
- (b) Not using different methods to teach math.
- (c) Not explaining math the way they have to use it in daily life.
- (d) Not doing reinforcement activities about every topic.
- (e) Not sparing enough time for each student.

They assumed that parent-related factors that cause math anxiety are -

- (a) Parent's pressure to get high marks.
- (b) Negative statements from parents.
- (c) Comparison with other students.
- (d) Not helping the children at home with their homework.

- (e) Not allowing the students to use math in their daily life.

Behavioral and Cognitive factors

Bandura (1997) provides evidence that self-efficacious students participate more readily, persist longer, work harder, and have fewer emotional reactions (all behavioral factors) when they encounter difficulties than do those who doubt their capabilities and strengths. Research shows that a person's math anxiety is mostly related to their future math performance (Jameson, 2013).

Curriculum and Academic factors

Geist (2010) believes the math curriculum used in school contributes to math difficulties. Because of the hectic schedule, the students will neglect the fact that why they have to learn math. The current curriculum of math is not providing a conceptual understanding of math, instead, it focuses on teaching them to by heart formulas and methods. Because of that children will forget them soon and undergo frustration (Ruff and Boes, 2014).

Time

An additional factor can be Time. Whenever a student comes to know that he will be having a test someday, this delay will cause fear to set in. He knows that he can't avoid it, so he starts to panic. The student combines the fear of not being confident enough to give the test, the uncertainty of being able to do the problems, and the urgency to complete everything on time which all together develops into math anxiety (Smith, 2004).

The following section of the article deals with the effect of mathematics anxiety on the achievement of students in mathematics. According to the Deficit Theory (Hembree, 1990; Tobias, 1986), low academic abilities may cause a high level of math anxiety. It can be caused by the previous negative experience with mathematics. This is in the case of students undergoing developmental problems from childhood. On the other hand, the Theory of Cognitive Interference suggests that a high level of math anxiety results in unsuccessful problem-solving. According to this theory math anxiety mediated by working memory, interferes with the ability to solve math problems, which results in low math achievement or avoidance of math content (Ashcraft & Krause, 2007; Morsanyi et al., 2014). Both theories are correct, both theories postulate that math anxiety and math performance can be interrelated. Both can cause and affect each other.

Some of the studies have focused on anxiety in math-related situations in general in which children were asked how anxious they felt when they were asked to do a mathematical problem. These studies reveal a connection between math anxiety and mathematics performance. Thus, it seems that anxiety in math-related situations is specifically related to performance in mathematics in contrast to anxiety about failure in mathematics. It has been suggested that math anxiety affects math performance straining working memory (Ashcraft & Kirk, 2001) as well as a long-term effect, which leads to the avoidance of situations involving mathematics.

Math anxiety and math performance link in Behavioral research

In behavioral research most of the findings are contradictory. Some researchers reported that there is an effect of math anxiety on math performance whereas other studies found no evidence of this effect. The negative effect of math anxiety may be dependent on task complexity, known as anxiety–complexity effect, where the effect of math anxiety was only observed in complex problems. Anxiety impairs processing efficiency (the effectiveness of performance). Students with high math anxiety showed marginally lower accuracy in complex tasks but no difference in reaction time (Young, 2012).

Math anxiety and math performance link in Psychophysiological research

Suarez-Pellicioni (2013) explored the effects of math anxiety on simple arithmetic processing and found that high math anxious students elicited more positive amplitude. They concluded that students with high math anxiety had difficulty suppressing attitudes. The effect of math anxiety is allocated to negative stimulus in numerical cognition. They summarized that simple arithmetic operations were not so simple to students with high math anxiety.

Math anxiety and math performance: The Role of Arithmetic Ability

Some individual factors such as motivation or arithmetic skills may affect the relationship between math anxiety and math performance. Lyons and Beilock (2012) have explored that not every student with math anxiety will perform poorly in math and suggested that control of negative emotional responses may help them to overcome the math anxiety. Math anxiety is negatively related to math achievement. After all, it leads to avoidance of math because it disrupts the working memory resources that students use to solve difficult problems at the moment (Ashcraft, Kirk 2001). Working memory is a chief cognitive construct involved in maintaining relevant information in a highly active state and inhibiting interfering information (Engle, 2002).

Some of the studies suggest that a drop in performance that can be attributed to math anxiety is independent of math achievement or an individual's competence. In early research, they found that math anxiety had very little effect on simple arithmetic in high school students because of memory retrieval (Ashcraft & Faust, 1994). But in more complex arithmetic problems they showed either slow performance or less accurate performance.

High math anxiety not only impairs math performance but also leads to lower motivation in mathematics, higher mathematics avoidance, less effort, and persistence in mathematical problem solving, and less likely to take math-oriented courses in further studies (Ashcraft and Krause (2007). The decline in mathematics performance with higher math anxiety can be explained by a divergent focus on cognitive resources. Individuals with high working memory have better learning performance due to the larger amount of cognitive resources. The worries and tension from math anxiety occupy the cognitive resources and divert the attention that could be otherwise used for the task (DeStefano & LeFevre, 2004).

When a math-anxious student asks to do a math problem he will not be able to do the problem accurately, because it affects his working memory, but if he is asked to do a reading or any other activity other than math problem solving he will be able to do, so this tells that anxiety is confined to only math domain and not imply to other disciplines (Lyons and Beilock, 2012).

Math anxiety can create a dual situation that will affect the working memory and lead to performing poorly in mathematics. The math-anxious students will ruminate on anxious students that divert mental resources from solving the problem. The idea that creating a dual-task will divert the attention away from the task, is called Distraction theory (Beilock and Carr, 2005). Ashcraft (2002) additionally notes that math anxiety impacts math performance. Beilock and Carr (2005) have explored that high working memory students will perform well in mathematics tasks. In anxiety-provoking situations, low working memory level students perform poorly. Low working memory students have fewer units of cognitive resources to compensate to work on the math task, they are unable to create a strategic plan to confront the task. Thus, individual differences have to be considered when discussing the math anxiety-performance link.

Discussion

Math anxiety is a problem that cannot be ignored, it has to be taken into consideration. There are many ways we can reduce math anxiety in the students and can help them to overcome it. As a teacher, we have to help the student to master mathematics. We can identify the students who are suffering from math anxiety and they have to be given extra attention. They may be avoiding math homework, they might sweat a lot when asked to solve a sum, they will not be understanding a single term, etc... There are so many other symptoms to identify in the classroom. These symptoms are the guidelines that will help the teacher to understand the students in-depth and help them out.

As a growing teacher, this research is very helpful, that the investigators have learned the factors of math anxiety and how math anxiety can affect math performance. It will help us to introduce effective strategies in the teaching-learning process. Making the teaching interesting is the most important part of the classroom. It will help the students to understand the concepts and make them more engaged in the activities.

The analysis of the first objective is that many factors affect math anxiety in different ways. The factors include students themselves, parents, teachers, academics, curriculum, cognition, environment, society, behavior, and gender. All factors affect math anxiety on an equal level. Not every student will be affected by the same factors, so the researchers have found many factors that may affect math anxiety. The main factors of all these are teachers, environment, and parents. These three factors play an important role in affecting math anxiety. Researchers have stated that different theories say that math anxiety may affect math performance and some others suggest that there is no connection between math anxiety and math performance. It can be the poor ability of the student, who can't perform math, which can eventually lead to math anxiety. Some say that math anxiety affects the working memory of the brain

which in turn causes poor math ability. Other research papers suggest that math anxiety and math performance is bidirectional- math anxiety can cause poor math performance and poor math performance can cause math anxiety.

Conclusion

Math anxiety and math performance are bidirectional. This research helps to understand what is math anxiety and how it affects math performance and the factors that affect math anxiety. It gives teachers an overview of how math anxiety can be overcome by the students. This will aid tomorrow's teachers with the correct information on how to identify a math-anxious student and how to help him to overcome that situation. We can make the main factors that may cause math anxiety to be incorrect way, so it won't affect the child. When untreated or if the teacher is not paying any attention to a math-anxious student it may lead to Math phobia. As responsible teachers, we have to guide the students and we shouldn't be an instructor but a guide to the students, according to Aurobindo Ghosh.

Declaration Statement for Conflict of Interest

The authors of the article declare that there are no relevant financial or non-financial competing interests to disclose.

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