Exploring the Effectiveness of Flipped Learning on Mathematical Triarchic Abilities Among Secondary School Students in India

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Abstract

One of the skills learned in mathematics is the capacity to deal with abstractions and a problem-solving strategy (NCF-2005). As a result, one of the major goals of mathematics in schools should be to mathematize a child’s cognitive processes (NCERT, 2006). The findings of ASER 2017: Beyond Basics suggest that school going children in India are still struggling to apply their mathematical skills in real-life circumstances. According to Cross (2005), the students who are actively involved in studying are more likely to learn than students who are not. In the flipped classroom, various active learning activities like think-pair share, brainstorming, discussions, presentations are conducted where all the students actively participate rather than passively receiving the information. In this context, the researcher conducted a study so as to make an attempt to increase the triarchic abilities (practical, analytical and creative abilities) of the students that is essential for students to be successful in life (Sternberg, 1999) by introducing an active learning strategy called flipped learning.

Introduction

Maintaining concentration and following one's assumptions through to their logical conclusions are two essential components of mathematical achievement. Math is necessary for anyone who desires to reach a level of professional fulfilment and financial stability in their career. The formalisation of a child's mental processes through the use of mathematical concepts needs to be the primary goal of a mathematics education. On January 16, 2018, a report titled ASER 2017: Beyond Basics was made public by the non-governmental organisation Pratham. Students between the ages of 14 and 18 are the focus of the ASER study that was conducted in 2017. The findings indicate that a significant number of young people struggle when it comes to putting their literacy and numeracy skills into practise in the real world. At this point in time, 10 percent of Indians fall into the age range of 14 to 18 years old. Teenagers are in the process of acquiring both the fundamental and specialised information that will be necessary for them to function well as adults. For today's youth to reach their greatest potential, they require the appropriate support.

Many children of school age do not reach their full potential because the methods of instruction they are exposed to are inefficient. Sternberg developed the "Theory of Successful Intelligence" (Sternberg, 1999) and a number of different teaching methodologies in order to satisfy the requirements posed by students as well as those posed by teachers. The psychological theory of intelligence that is utilised in teaching for success in intelligence is one that has been demonstrated to be successful. The primary assumption of this concept is that in order to be successful in life, an individual needs to be in possession of a particular skill set (triarchic in nature). Sternberg contends that in order to achieve success, an individual must first define that term for himself within the context of his particular sociocultural setting.
A person is considered to be a practical thinker if they are able to recognise what they are lacking in order to flourish and then design tactics to achieve it. They are able to work effectively with people to accomplish goals, and they have a solid understanding of the strategies that do and do not succeed in their industry. An analytical mind can be recognised by academic success, which manifests itself as excellent grades, strong performance on tests, and an overall appreciation of studying. The process of intentionally altering one's mental operations in order to arrive at a conclusion that is logical is what is meant to be understood as the ability to think analytically. Critical thinking and the capacity to make intelligent decisions are the two most crucial talents that must be demonstrated. Making a decision is a process, and at the end of that process is either the evaluation and selection of different options or the appraisal of different possible outcomes. This man is capable of thinking in unique ways, coming up with new and interesting ideas, and carrying them out all on his own. His capacity to think synthetically and make links between ideas that at first glance seem to have no bearing on one another is one of his talents. A person is said to be creative thinker if they are capable of innovative ideas as well as imaginative activity. Sternberg and Lubart (1995a, 1995b) assert that original thinkers are similar to successful investors in the sense that they have the ability to "buy low" and "sell high" by acting contrary to the received opinion. A person who possesses true creative ability will have a balanced set of qualities that include creative, analytical, and practical skills.

In the year 2014, the Flipped Learning Network was the first organisation to begin using the phrase "flipped learning." The definition of flipped learning-

"a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the education guides students as they apply concepts and engage creatively in the subject matter." (Flipped Learning Network [FLN], 2014, Para.1)

As students receive direct instruction during their own independent study time, there has been a change away from an emphasis on group instruction and toward an emphasis on individual instruction. Instead of being the place where students are exposed to new concepts, the classroom should be viewed as their own private space. The classroom is a typical example of a place designated for group activities. As of the year 2018, the Academy of Active Learning Arts and Sciences (AALAS), a non-profit organisation, has been hard at work on a project to develop global flipped learning standards. This was produced by the collaborative efforts of six chair people, one hundred international delegates, practitioners of flipped learning, researchers, professors, education technologists, and learning professionals from 49 countries. One of the numerous benefits of flipped learning is that it allows students to learn at their own pace, which benefits both the individual students and the classroom as a whole (Long, Cummins, & Waugh, 2016). Interactions between students and teachers that are of a high quality appear to be beneficial for a number of aspects of students' development, including their ability to acclimatise to school, their social skills, and their academic achievement (Kaufman & Sandilos, 2011).

Need for the Study

Although the effect of flipped learning in higher education has been documented (e.g., Florence, 2017; Ghafoor, 2019; Priyadarshini, 2019; Sickle, 2015; Vasilchenko, 2017), it is essential to examine the impact of flipped learning at K-12 settings (Akcayir & Akcayir, 2018; Lo et al., 2018). Moreover, the effect of flipped learning on higher order thinking skills, critical skills or triarchic abilities is also not well researched. In order to address these
gaps, the researcher conducted this study to investigate the impact of flipped learning on mathematical triarchic abilities namely practical abilities, analytical abilities and creative abilities among secondary school students and record the perceptions of the students, teachers and the instructor on flipped learning.

Research Questions

RQ1: What is the effect of flipped learning on triarchic ability of secondary students in mathematics?

RQ2: What are the perceptions of the participants on flipped learning?

Theoretical Framework

The flipped learning classes that were utilised in the study were constructed with the assistance of Merrill's (2002) First Principles of Instruction and Anderson and Krathwohl's (2001) Revised Bloom's Taxonomy. Both of these resources were utilised in order to carry out the research. Merrill (2002) presented five principles after conducting an analysis of numerous different methods of instructional design. These are the "Problem-centered principle," the "Activation principle," the "Demonstration principle," the "Application principle," and the "Integration principle." The flip session of the flipped learning class consisted of what was called the "Activation, Demonstration, and Application phase." The Problem-centered Environment practise session that was held in the flipped learning class incorporated all of the educational phases, including "activation," "demonstration," "application," and "integration." The revised version of Bloom's Taxonomy divides cognitive processes into six distinct levels: recall, comprehend, apply, analyse, and evaluate. The final level is creation. The "Flip" session of the flipped learning class consisted of the learning components "Remember," "Understand," and "Apply." The practise session for the flipped learning lesson included the cognitive processes of "Applying," "Analyzing," "Evaluating," and "Creating," respectively.

Literature Review

The purpose of this study was to fill in some of the gaps in the existing literature on flipped learning in mathematics. According to the published material on flipped learning in a variety of fields, the vast majority of research is conducted in higher education, whereas only a very small number of studies are conducted in K-12 institutions (Akcayir & Akcayir, 2018). According to the reports from the Indian studies, the majority of the research that was done was in the STEM fields, which are comprised of science, technology, engineering, and mathematics. The studies that were looked at for the flipped learning in mathematics found that the majority of the research was done in higher education (Yang et al., 2019), despite the fact that flipped learning is beneficial at all levels of education. Even very little is known regarding the effectiveness of flipped classrooms in K-12 settings compared to classrooms that do not use the flip learning model (Lo et al., 2018). The United States of America is the location of the majority of the research on flipped learning in mathematics in K-12 settings. On the other hand, according to Lo & Hew (2017) very few research projects have been carried out in other nations such as Taiwan, Canada, and England. Based on this information, it appears that researchers in other countries are only getting started with experimenting with flipped classrooms.
Some researches came to the conclusion that when it came to learning performances, pupils fared better in flipped classrooms as opposed to traditional classrooms. According to the findings of some studies, both groups fared equally well (e.g., Braun et al., 2014; Saunders, 2014). Even further, the literature uncovered the fact that students' impressions of flipped learning remain confusing due to the fact that they are of a mixed character. This presents a problem for the field of mathematics education. There is a paucity of research that examines the impact that flipped classrooms have on students' critical thinking abilities or higher order thinking skills in the field of mathematics. The majority of studies looked at students' performance in mathematics (e.g., Katsa et al., 2016, Hwang & Lai, 2017, Lo & Hew, 2020).

The researcher was able to better design and decide on the intervention's flipped practise session activities because to the information gleaned from the literature review. Almost universally, students in these studies (e.g., Schmidt & Ralph, 2016, e.g., Braun et al., 2014; Charles-Ogan & Williams, 2015; Kennedy et al., 2015; Salimi & Yousefzadeh, 2015) were first exposed to the material via video lessons before ever setting foot in a classroom. During the flipped class session, the researcher opted to hand out the course materials to the students in the computer lab. Pre-class formative assessment of learned material was advocated for in the literature (e.g., Schmidt & Ralph, 2016; Heo & Choi, 2014; D’addato & Miller, 2016; Hwang & Lai, 2017). With this research, the researcher incorporated a recap and test into the flipped classroom's rehearsal session. She had the students do a lot of work out of their math books and offered them analytical issues to discuss in small groups.

Numerous iterations of the flipped learning model, such as the "classic flip" (Vasilchenko, 2017) and the "flipped mastery" model, have been put to the test (Wiginton, 2013). In contrast, the review of the relevant research conducted by one researcher turned up no papers on the "in-class flip model."

Methods

Research Design

An explanatory sequential design of mixed methods methodology was utilised in this study, as suggested by Creswell and Plano Clark. The purpose of the study was to investigate the effects of the flipped learning strategy as well as the traditional learning approach on the triarchic mathematical abilities of secondary school students (2011). This strategy can be broken down into two distinct but interconnected phases: (1) a quantitative phase, during which data is gathered and analysed with both descriptive and inferential statistics, and (2) a qualitative phase, during which the results from the quantitative phase are interpreted and contextualised.

(1) Quantitative Phase

During the quantitative phase, we employed a sampling method that was similar to an experiment and involved purposeful sampling of the data. A quasi-experimental pretest-posttest control group technique was chosen for the quantitative phase of the study because randomization was not allowed by the authority of the selected school in order to avoid the interruptions in normal school functioning. The research was conducted using a design known as non-equivalent groups, which means that the pre-test and post-test groups were not identical. In addition, the results of a mathematical triarchic test, which included a mathematical practical test, a mathematical analytical test, and the Sharma and Sansanwal Mathematical Creativity Test, were compared before and after Flipped Learning was implemented to determine the effectiveness of the method. Analysis of Covariance (ANCOVA), a statistical technique, was applied to the quantitative findings in order to

63
(2) Qualitative Phase
In order to provide context for the quantitative findings, the qualitative phase consisted of a thematic analysis of interviews with students, math teachers, and the reflective notebook kept by the instructor.

Procedure
There were 179 ninth graders from the 2019-2020 school year who took part in the study; 90 were assigned to the experimental group, and the other 89 served as a control. Over the course of 24 weeks, the study was conducted. During the course of a research study, students were instructed in seven different mathematics chapters from the CBSE NCERT textbook. In the traditional classroom, the lecture covered the chapter, and the home assignment consisted of working through the exercises in textbook. Students in flipped classrooms organised according to the flipped classroom model and were given access to fresh information in the form of online videos on YouTube in the Computer laboratory in school. After that, they took part in exercises that required them to apply what they had learned. They were required to work together in class on a mathematics exercise that was taken directly from the textbook. The instructor provided assistance to the students with their respective assignments. After that, we gave them 4 analytical problems to solve, and it was up to them to think of 2 creative problems on their own. For the purpose of gathering information, the researcher developed and carried out pre- and post-tests. The perceptions of the 9 students and 3 teachers were collected via students’ interviews. For in-depth insights, even the perceptions of the instructor were recorded and reported.

Data Analysis
Descriptive Analysis
Mean and standard deviation were calculated to characterise the data and its tendencies. The data was also presented graphically for easier comprehension.

Inferential Analysis
An analysis of covariance, also known as an ANCOVA, was carried out with pre-test scores serving as a covariate in order to compare the levels of mathematical triarchic ability possessed by the control group with the experimental group. It handled the variation that occurred within the group by removing the inequalities in the baseline measures.

Thematic Analysis
The perceptions of the students were collected via students’ interviews. In the flipped class, a total of 9 students were interviewed. The interviews took place in English and were transcribed in English. Each respondent was given a unique identification, with Student H, Student M, and Student L designating students from the clusters of (1) high achievers, (2) medium performers, and (3) low performers. The interview transcripts of students and teachers and reflective journal maintained by the instructor in the course of intervention were analysed through the technique of thematic analysis.
Findings

Results of Analyzing Quantitative Information

Mean scores on the Pre-Test Measure of Mathematical Practical Ability did not differ between the Experimental and Control Groups. The average mathematical practical ability of the experimental group improved by 17.33 points between the pre- and post-tests, while the control group improved by only 10.70 points. When controlling for Pre-Mathematical Practical Ability, the adjusted mean score of Mathematical Practical Ability for the Experimental Group is 42.71, which is considerably higher than that of the Control Group, which is 36.88. When students' pre-mathematical practical ability is considered as a covariate, the Flipped Learning Strategy was found to be much more effective than the Lecture Method in fostering students' mathematical practical ability.

Average pre-test scores on a measure of mathematical analytical ability show no significant difference between the experimental and control groups. In terms of gains in mathematical analytical ability, the experimental group demonstrated a respectable increase of 15.77 points from pre- to post-test, while the control group demonstrated a smaller gain of 9.42 points. When controlling for Pre-Mathematical Analytical Ability, the adjusted mean score of Mathematical Analytical Ability for the Experimental Group is 35.67, which is considerably higher than that of the Control Group, which is 29.03. Taking students' Pre-Mathematical Analytical Ability into account, it was discovered that the Flipped Learning Strategy is substantially more effective than the Lecture Method at fostering students' Mathematical Analytical Ability.

The average pre-test scores on a test of Mathematical Creative Ability between the Experimental and Control Groups are not statistically different. The average mathematical creative ability of the experimental group improved by 338.10 points between the pre- and post-tests, while the control group improved by only 27.42 points. When controlling for Pre-Mathematical Creative Ability, the adjusted mean score of Mathematical Creative Ability for the Experimental Group is 514.12, which is significantly greater than that of the Control Group, which is 203.61. When students' Pre-Mathematical Creative Ability was used as a covariate, it was shown that the Flipped Learning Strategy was much more effective than the Lecture Method at fostering students' Mathematical Creative Ability.

The mean Mathematical Triarchic Ability scores of the Experimental and Control Groups before treatment are not statistically different. Mean mathematical triarchic skill increased by 370.96 points in the experimental group from pre- to post-test, while it increased by only 47.12 points in the control group. Adjusting for Pre-Mathematical Triarchic Ability reveals that the Experimental Group had a considerably higher adjusted mean score of Mathematical Triarchic Ability, at 592.52, than the Control Group, at 269.50. When students' Pre-Mathematical Triarchic Ability is used as a covariate, the results show that the Flipped Learning Strategy is much more effective than the Lecture Method at fostering their Mathematical Triarchic Ability.

In the quantitative results, it was found that when students' Pre-Mathematical Triarchic Ability was used as a covariate, the Flipped Learning Strategy significantly outperformed the Lecture Method in fostering their Mathematical Triarchic Ability (Mathematical Practical Ability, Mathematical Analytical Ability, and Mathematical Creative Ability).
Figure 1

*Mean Test Scores for Experimental and Control Groups on the Mathematical Triarchic Ability Test, Both Before and After Treatment*
Results of Analyzing Qualitative Information

The interview transcripts of the students, teachers and the instructor were analyzed to get their perception on flipped learning. It was divided into different themes – perception on flip sessions and practice sessions. The findings are: after class activities, seeing the video again helps, extra handouts that covered the same material as class notes helped in exam cramming, WSQ answered their internal inquiries well, the recapitulation of classmates helped students examine and apply new information to the text's exercise problems, the quiz gave them confidence, students shared ideas to find multiple solutions to the same problems, both pupils who helped their peers solve problems and explain concepts profited, students supported each other throughout class exercises, students solved analytical difficulties faster by working together. Some other findings were-the teacher helped kids quickly, questions built confidence, more practise station drill helpers would have been nice, analytical problems required extra class time, rearranging chairs was important for group work. Some of the other benefits emphasized in the interview were that-Flipped classrooms assist students by including parents, Rewatching instructional movies cut down on classroom repetition, WSQ improved student progress evaluation, class participation increased, Complex questions dominated class time, immediate feedback helped students, documenting student growth helped teachers evaluate student work and its effects on the classroom. Every child participated in the joint project and higher-level cognitive questions stimulated discussions. Student presentations enhanced self-esteem and performance and learning grids let teachers track student progress. Flipped learning relies on a good instructor-student relationship, which affects student retention.

Few suggestions offered by teachers and instructor were that the furniture configuration hindered their class. children may have used classroom objects to indicate their needs and obtained prompt assistance in the teacher's absence, the best educational films simplify complex topics. The WSQ approach should be used for assessing student development, quizzes
should also be used as they are helpful for assessing student progress, during the flipped lesson, the instructor could aid each student individually.

According to the qualitative analysis of the interview transcripts of the students, math teachers, and the reflective journal of the instructor, the primary reasons for the improved performances of the experimental group were the Formative Assessments, improved interactions between teacher and students, increased peer interactions, increased confidence in solving problems, increased in-class time for practising math problems, and individual attention to the students. Other reasons included increased in-class time for practising math problems and increased in-class time for completing formative assessments.

**Educational Implications**

Several areas of education can benefit from the findings of this study. The research concluded that classroom interactions, both those between students and those between students and the teacher, significantly increased student learning. Therefore, it is important to facilitate as much student-teacher and student-peer interaction as feasible in the classroom. One reason for this uptick in achievement is that students have had more time in class to work on arithmetic problems. Therefore, pupils should increase their in-class math practise. When compared to more conventional methods of instruction, flipped classrooms were found to have a significant impact on students' development of transferable skills including problem solving, analysis, and innovation. Therefore, it is essential that educators be encouraged to incorporate this cutting-edge method into their classrooms. They can incorporate formative assessments into their lessons, such as quizzes or brief reviews of previously covered material. As the WSQ technique proved useful in gauging the students' progress, it may be implemented by educators. The teachers interviewed all agreed that parental participation in their children's education was crucial. Therefore, parents can also be informed about the significance of employing this flipped learning models based instructional material in order to improve their children's academic outcomes.

Based on the findings of this research, it is clear that access to computers and the internet is crucial for the widespread adoption of the flipped learning approach. Therefore, the school should have internet-connected computer laboratories so that teachings can be flipped during class time. It is the responsibility of educational institutions to support their faculty members as they pursue training in the flipped classroom approach. A section on Flipped Learning should be included in pre-service teacher education programmes so that future educators have exposure to and experience with this active learning technique. Policymakers need to be educated on the value of the flipped learning strategy as a cutting-edge method of instructing secondary school students. The federal government may try to fund the installation of computer networks in all public schools. If we are serious about improving education, we must provide teachers with opportunities to learn about and practise the flipped learning technique.

**Conclusion**

Mathematization of students’ abilities is important but achieving this along with adhering to the curriculum can be a herculean task. Thus, the researcher carried out an explanatory sequential design of mixed method study to find out the effect of flipped learning on mathematical triarchic abilities among secondary school students. It was found that Flipped Learning technique has improved Triarchic Abilities namely Mathematical Practical Ability, Mathematical Analytical Ability and Mathematical Creative Ability in secondary school.
students. As the innovative strategy is found effective, it has its implications for students, teachers, parents, educational institutes, teacher training institutes, policy maker and government for bringing quality of students’ learning in mathematics. In view of this, all in all it can be said that Flipped Learning strategy has its worth to be implemented in the teaching-learning process in the school stage.

Limitation and Recommendation

The research does come with a few important limitations. To begin, given that the study was carried out in the field of mathematics, it is unreasonable to presume that the findings will be applicable to other disciplines. One of the disadvantages of the study is that it only targeted students in grades K-12. If the research project were carried out at a more advanced level of mathematics, it would be possible to collect and compare the points of view of students in both settings. If additional questions were asked, it would be easier to understand both the possible advantages and disadvantages of using the flipped classroom strategy for teaching mathematics. Only nine students were chosen to participate in the interview process for the flipped class. The percentage of volunteers who agreed to take part in the semi-structured interviews was considerably lower than what was anticipated. As a consequence of this, it's possible that the perspectives of a few of the students were ignored in this research. In this study, students mostly used desktop computers to view instructional videos. As smartphones decrease in price and increase in availability, more and more students are opting to watch films on their mobile devices instead of their computers. Very little investigation has been made into the effects of mobile education. Examining students' perspectives and sentiments on using mobile phones to watch flipped classroom videos would widen the scope of flipped pedagogy research. Educational research has shown that students' individual learning styles affect their academic performance. More studies on the flipped classroom are required to better understand the role that learning style plays in students' achievement, motivation, and confidence. Researchers who are interested in implementing the flipped classroom should also look to the latest findings in cognitive science and education while planning and executing in-class activities. Academics should examine whether or not a specific field is more open to flipped learning studies than others. Students from both rural and urban settings were excluded from the analysis. Therefore, a large-scale study can be done to compare the results of the study with those of students in both urban and rural settings.

References


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