

EFFECT OF TEACHING BY STEM APPROACH IN SENIOR SECONDARY SCHOOLS

P. Alam¹, N. Ram²

¹Assistant Professor PSR Govt. Degree College Tyuni, Dehradun, India 248199

² Assistant Professor HVM (PG) College Raisi, Haridwar, India 247671

ABSTRACT

The aims of this paper to know the effect of science, technology, engineering, and mathematics (STEM) on both innovative thinking and mathematical achievement. For this, quasi-experimental method has been adopted with an experimental design for two groups, one experimental and the other a control. The research sample consisted of 50 male and female students from the HVM senior secondary school Raisi, Haridwar. The sample is chosen intentionally and divided into two groups: first control groups studying by the traditional method, their number is 25, and second an experimental group that applied the STEM approach, their number also 25. There are parity between the two research groups in the variables (chronological age, previous achievement in mathematics, innovative thinking). The research tools consist of testing innovative thinking skills as like fluency, flexibility, originality, relationships and achievement tests. The research experiment is applied before and after. To test the validity of the hypotheses, data are collected and then statistically analyzed using t-test (statistical methods). The results of the research found that there are statistically significant differences in both the test of innovative thinking and mathematical achievement in favor of the experimental group that studied according to the STEM approach.

KEYWORDS—mathematical achievement, STEM approach, innovative thinking

INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) approach is considered important by many countries and projects carried out in order to integrate into their curriculum. The widespread use of STEM is only possible if teachers have positive thoughts, knowledge and experiences about it¹. The importance of ensuring students with a strong education in STEM has been emphasized². Teaching approaches related to STEM are now considered as one of the most emerging areas in the context of education in both developed and developing countries³. Economically developed countries such as the USA, England, and Japan felt the need to invest in STEM education-related fields for the future. These countries carry out many implementations for STEM in governmental and non-governmental organizations, scientific institutions, universities, and schools.

STEM was first mentioned by The National Science Foundation director J. A. Ramaley in 2001 and spread rapidly after this date⁴. STEM is an education term consisting of the initials of science, technology, engineering and mathematics. There is a need for individuals with 21st-century skills such as innovative thinking, decision-making, problem-solving, entrepreneurship, communication, collaboration, responsibility, and creativity. One of the educational approaches in which these individuals are nourished is the STEM approach⁵⁻⁶.

STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) ENTRANCE

STEM Education has become a top priority for reforming educational processes that adopt integration between academic subjects, as the cries have risen for this over the past two decades, while the STEM approach has proven its effectiveness after its application, especially in the United States of America⁷. Consequently, at the beginning of the discussion about the integrated STEM entrance, we have to know what this entrance is, it reflects the first letters of the four words; science, technology, engineering, and mathematics, it's far a pedagogical approach that seeks to combine teaching and learning of those 4 fields, it wishes environments prepared for this reason, in which college students exercise activities, research tasks, workshops, etc. It motivates students and makes gaining knowledge of and leisure that pushes students in the direction of reaching an extra complete and coherent knowledge and distances them from the same old deaf memorization⁸. It is an entrance to education, in which the natural sciences, engineering, mathematics interact through experimental educational tools and experiments, in which the learner designs products within projects that help him to employ and develop concepts through higher mental skills⁹⁻¹⁰. The importance of the STEM entrance for teaching mathematics is obviously the relationship between this entrance and teaching mathematics. It is a proposed entry for teaching including engineering, mathematics, mentions that the entrance to science, technology, engineering, mathematics

at all SSC school levels, because it enables the learner to develop his skills in mathematics in order to reach creativity, outstanding performance¹¹⁻¹².

The role of the teacher is inevitable in the easy adaptation of innovations such as STEM to the education system and in overcoming the problems encountered. Teachers' perceptions and preparedness really affect the success of the implementation of STEM education. They need to have adequate prior training and understanding in order to teach STEM activities to their students. However, teachers' perceptions and beliefs that form their approaches and methodologies for the implementation of new educational reform are usually disregarded.

The role of the teacher and the learner in applying the STEM approach as below:

Table 1. Entrance STEM Integrative¹³

S.No	The role of the teacher	The role of the learner
1	Creating an environment for active and effective learning by directing students and guiding them towards positive participation in learning and activities.	Active and positive participation in the learning process and activities.
2	Realizing students' characteristics and taking into account their differences.	Finding positive solutions to specific situations and problems.
3	Designing the teaching process in line with their preparations.	Producing new knowledge within the available knowledge within the scope of knowledge integration.
4	Encouraging students towards meaningful learning.	Collaborate with peers and communicate with them positively, and work effectively within a team.
5	Involve students in brainstorming and thinking training sessions.	Discovery, investigation, research, and planning for implementation.
6	Raising the self-motivation of the learner towards participation and learning.	Evaluation and amendment under the feedback.
7	To develop himself professionally in the four disciplines as much as possible.	Flexibility with others and accept opinions and discussions with scientific evidence.

INNOVATIVE thinking

Innovative thinking is the most outstanding intention inside the standards of the incorporated STEM approach; as most of the goals of this approach is to are seeking for to provide students with abilities, the maximum vital of that are science abilities, mathematical capabilities, research capabilities, creative problem-solving, technological, programming abilities, and better thinking capabilities, on top of that is progressive wondering, with the students' use of logical reasoning in creativity tactics¹⁴⁻¹⁵.

Scientists differed among themselves on a unified definition of innovative thinking due to the multiplicity of schools of thought of researchers as well as their scientific interests. The word "creativity" is originally a word derived from the Latin "creare" meaning creating or inventing something, so innovation here is meant to produce something new that was not produced before that. It is an intellectual activity in which the student becomes sensitive to problems, able to identify the deficiencies, gaps of information with the ability to formulate questions, formulate hypotheses about those problems, and test the validity of solutions so that he can reach original solutions that are not repeated, thinking characterized by the emergence of abundant, varied, new, original ideas¹⁶⁻¹⁷. The research relies on innovative thinking skills appropriate to mathematics, developed by Glyphord and Torrance.

1. **Fluency:** Fluency is the ability to generate the largest number of ideas, with those ideas related to the topic, and these ideas may be represented in the form of terms, expressions, or drawings¹⁸⁻¹⁹.

2. **Flexibility:** Flexibility is the ability to produce ideas in a rapid and varied manner as the individual changes his thinking orientations in a way that suits the situation or the problem at hand and according to the influences as these influences are characterized by a variable nature²⁰⁻²¹.

3. **Originality:** Originality is the use of thinking in an unusual way, the response that is not familiar and unique, in which ideas flow in a free way to obtain many ideas in a short period.

4. **Relationships:** Relationships means the student's ability to create relationships between what he learns, it usually defines similarity, symmetry, and difference²².

MATHEMATICAL ACHIEVEMENT

Achievement considered as the ability of the learners to understand, assimilate the study materials and their contents through the learner's perception of the relationships between the information included in the contents of the course, the facts and concepts that he extracts from them that will be subsequently reflected on his performance in the tests that measure this, whether they are written or oral tests, at any time determined for their conduct. As for mathematics achievement, it is the results of what students learn from the elements of mathematics, it is considered an indicator of the success of one of the teaching strategy that was followed in learning, in a certain period and is usually measured by an achievement test prepared for this purpose²³⁻²⁴. Some factors affect students' academic achievement, such as ways of thinking, habits of mind, motivation, self-concept, in addition to dealing with information, obtaining it, making decisions about it, and these factors may be affected by external factors that contribute to its development, including teaching methods and strategies for developing these aspects²⁵. The researchers add that measuring academic achievement determines the success of teaching methods, the effectiveness of the teaching strategies used in the teaching process, the positive impact of the teaching approaches used, the success and distinction of the teacher, the success of the educational and school system as a whole.

LITERATURE REVIEW

Learning mathematics is one of the most important pillars of the teaching and learning process, especially in the current era in which mathematics has intertwined with the world of computing and programming²⁶⁻²⁷. It has increased its importance and the importance of learning it, with the constant complaint of students about learning that subject, and their low mathematical achievement. It was imperative to seek modern and effective methods and approaches for teaching mathematics. Among these approaches, the Integrated Introduction to STEM and its abbreviation where teaching by the STEM entrance works on the integration between the information acquired within mathematics as a central subject with other subjects, namely science, technology and engineering²⁸. It creates an integrated knowledge that enables the student to understand mathematics more easily, helps him in solving mathematical problems, and designing innovative products in mathematics classes, where the numbers enter Mathematics and calculations and mathematical relations in the aforementioned subjects, thus mathematics is a starting point for student's learning and expanding their knowledge in the four disciplines. The scope of methods and curricula for teaching mathematics, many types of research and studies have been conducted to identify the importance of the STEM approach and its impact on mathematics learning and achievement²⁹. Where it proved that the entrance has a positive effect on the achievement of science, mathematics, the development of thinking skills in general, including, for example, mathematical thinking, some creative thinking skills, conceptual comprehension, and life skills³⁰⁻³¹. The mathematics in textbooks that students learn; is far from what students need in terms of mathematical knowledge in other subjects such as science³²; because mathematics is the subject of the mind and thinking, the development of thinking skills, especially innovative thinking, is necessary to study mathematics, despite this, many studies have shown that there is a decline in the levels of innovative thinking among students, and accordingly, we need what helps the development of this thinking since the STEM approach is primarily based on research, investigation, experiment, innovation, it will surely help students develop their innovative thinking skills. In addition to what studies have proven, the two researchers see, based on their experience, that there is an urgent need to change a teaching entrance that helps the teacher and the student in teaching mathematics, attracts students, links between life and its problems, by using principles, theories, laws of mathematics, which is expected to happen with the application of the STEM entrance³³. The research derives its theoretical importance³³ from its uniqueness applying the STEM approach to two variables at the same time, which are innovative thinking, mathematical achievement³⁴. The STEM approach is a topic despite its importance, but it did not meet the attention it deserves, then the research will help enrich the educational library and open horizons for the application of modern teaching approaches. Also, the research reflects the newly applied integrated teaching methods and approaches internationally by presenting an overview of the STEM approach³⁵. As for its practical importance, it is derived from the fact that it is field research that applies to teach according to the STEM approach, contributes to drawing the attention of those in charge of the educational process, whether they are curriculum designers, educators, teachers, to follow modern approaches, especially integrative ones. Research tools such as a test to measure the mathematical achievement of SSC students and another to measure innovative thinking in future educational

research may be used. The research provides a booklet for the teacher with lessons designed according to the STEM approach, and it represents a guide for him to develop more lesson plans in mathematics in the light of this entry³⁶. At last, but not least, the research provides instructional plans and activities designed according to the STEM approach that may help mathematics and science teachers later in facilitating the teaching of some mathematical and scientific concepts and principles.

HYPOTHESIS

- There are no statistically significant differences (level of significance is 0.05) between the mean scores of the experimental group (studied by STEM approach) and the control group (studied in the usual way) in the innovative thinking test of scientific SSC level students.
- There are no statistically significant differences (level of significance is 0.05) between the mean scores of the experimental group (studied by STEM approach) and the control group (studied in the usual way) in the mathematics achievement test of scientific SSC level students.

RESEARCH METHODOLOGY AND FORMULATION

The present research is based on the quasi-experimental method and the research design is experimental from two groups, one of them is control and the other is experimental, as shown in Table (1). The research sample is chosen intentionally, as it is represented by a group of students of SSC level School for girls as well as boys, numbering 50 students, it was divided into two groups, the control, which studied in the traditional way numbered 25, the experimental one that studied using the STEM approach, their number 25 students also. As for the procedures for controlling parity of the research sample, the two research groups were rewarded with several variables as previous knowledge, chronological age, previous mathematical achievement and innovative thinking test. These variables were determined by obtaining information on chronological age, previous achievement in mathematics from records. As for the previous knowledge, the students' grades were obtained after testing them, examining their answers, determining the grades of each of them. When a comparison is made between the mean scores of the experimental and control research groups using the t-test for two independent samples, it is found that the calculated t value is less than the tabular value of the variables, which means that the two groups are equivalent to the mentioned variables.

Table 2. The experimental design of the research

Groups	Previous Application	Experience	Post application
1. Experimental Group 2. Control Group	The pre-application for the mathematical achievement test and the innovative thinking test	1. Teaching by STEM approach 2. Teaching by the traditional way	Post application of mathematical thinking test, logical.

RESULTS AND DISCUSSION

To test the validity of the first hypothesis of the research, the Innovative Thinking test was applied in dimension to the two groups. The t-value is calculated to identify the significance of the differences between the experimental and the control in the test and the t-value was calculated to identify the significance of the differences between the pre and post measurement of the experimental group in the same test. It appears that there are statistically significant differences at the level of significance (0.05) between the mean of the experimental scores that are studied according to the STEM approach and the control in the post-measurement of the innovative thinking test in favor of the experimental group, as the calculated value is greater than the tabulated value, which means rejecting the hypothesis, which indicates the level of innovative thinking skills improved among SSC students. This indicates that the independent variable STEM input has an effect on the first dependent variable or has the effect of changing the level of innovative thinking skills of the members of the experimental group for research, this shown in Tables (2) and (3).

Table 3. The value of the t-test and the level of statistical significance for the differences between the experimental and control group in the innovative thinking test

Groups	No.	Mean	Standard Deviation	t-Test Tabular	t-Test Calculated	Significance Level
Experimental	25	41.2	7.21	1.86	3.95	.05
Control	25	37	7.06			

Table 4. The magnitude of the impact of STEM on innovative thinking

Independent Variable	Dependent Variable	The value of d	η^2
Teaching is according to STEM	Innovative thinking	1.082	1.079

In order to test the validity of the second hypothesis for the research, the mathematical achievement test is applied in dimension to the experimental group and the control group. The t-value is calculated to identify the significance of the differences between the experimental and control group in the achievement test and the t-value is calculated to identify the significance of the differences between the pre-measurement. The posture for the second experimental group in the test and is illustrated in Table (4). It appears that there are statistically significant differences at the level of significance (0.05) between the mean of the experimental scores that are studied according to the STEM approach and the control in the post-measurement of the achievement test in mathematics in favor of the experimental. As the calculated t-value is greater than the tabular t-value, which means that the hypothesis is rejected. This indicates an increase in the scientific achievement of SSC students in mathematics among the members of the experimental group, who are taught by following the integrated approach to science, technology, engineering, and mathematics. The results also indicate that there is a positive effect of teaching according to this approach on student achievement, to know the size of the effect, the formula for the directed effect size complementing the statistical significance is applied in light of the values of the t- test. This indicates that the independent variable STEM input has an effect on the second dependent variable or has an effect on raising levels of achievement of the members of the experimental group for the research, as shown in the tables (5) and (6).

Table 5. The value of the t-test and the level of statistical significance for the differences between the experimental and control group in the mathematical achievement test

Groups	No.	Mean	Standard Deviation	t-Test Tabular	t-Test Calculated	Significance Level
Experimental	25	42	7.16	1.85	3.95	.05
Control	25	36	7.05			

Table 6. The magnitude of the effect of STEM on mathematical achievement

Independent Variable	Dependent Variable	The value of d	η^2
Teaching is according to STEM	Innovative thinking	1.086	1.067

FINDING

The findings of the two researchers through the statistical treatment of the first hypothesis related to the effect of the STEM approach on innovative thinking among students is evident from the non-acceptance of the hypothesis as it has been proven that there are statistically significant differences between students in favor of the experimental group, which indicates the effect of the positive approach on the development of innovative thinking skills among students and attributing. That is because one of the teaching principles in the STEM entrance is the phrase from think to thing, which means transferring ideas into tangible products, a principle that leaves no room for doubt that this approach is based on innovation, creativity, and then it encourages students to innovate, thus that students, while learning through the integrated STEM approach, connect the four fields of science, technology, engineering, mathematics in an atmosphere of

generating new ideas, creating original works that do not exist before, through experimentation, practical practice, which is one of the innovative thinking skills. The strategies that are employed within the STEM approach, including cooperative learning, brainstorming and others, are strategies that work to involve students in the educational process, link experiences with theories, principles, and laws of mathematics, all of which develop students' innovative thinking skills, especially fluency, flexibility, and originality. As for the skill of relationships, the STEM approach is one of the most appropriate approaches to develop this skill, as it helps students to find the relationship between theoretical; life matters; the relationship between subjects and some of them within the same subject or across the four disciplines, the student must employ various relationships, equations, so on. Within the learning of these materials, especially that the STEM entrance deals with them as if they were one major specialty, which helps to develop the skill of finding the relationship between symmetry, similarity, and others.

Results related to the effect of the STEM approach on mathematical achievement: It is evident from the results obtained through the statistical treatment of the second hypothesis related to the effect of the STEM entrance on mathematical achievement among students. The hypothesis is not accepted as it has been proven that there are statistically significant differences among students for the benefit of the experimental group, which indicates the effect of the positive approach on raising the level of achievement in mathematics among these students of science, due to the fact that the integrative nature of the STEM approach increases students' acquisition of mathematical concepts in a smooth, accessible manner, where students see themselves, work with their hands in applying mathematics in other subjects Science; for example; which leads to a high level of mathematical achievement for them.

The use of the STEM approach in teaching made learning mathematics, meaningful learning in which the relationships, linkages between previous, new knowledge are understood, which enhances students' comprehension and thus increases their academic achievement. Linking mathematics learning with other subjects, such as various technologies, science, engineering designs, creates an atmosphere of enthusiasm that attracts students to mathematics and improves their motivation to learn and then increases achievement. The STEM approach transforms abstract mathematical concepts into concrete experiences, practices, and applications so that the concepts take root in the minds of students and last for a longer period, thus improving the level of mathematics achievement. The evaluation takes place within the STEM entrance in several ways under the name of alternative evaluation, such as achievement files and others, and the feedback provided to students within the assessments is a reason for improving their performance and thus their academic achievement. The fact that work and learning within projects in light of the STEM integration approach in the form of work teams in which students exchange views, ideas is one of the reasons for the survival of information and the stability of mathematics laws without the need for deaf memorization.

CONCLUSIONS

The t-value 3.95 is greater than the tabular t-value 1.85, which means that the hypothesis is rejected. The results indicate an increase in the scientific achievement of SSC students in mathematics among the members of the experimental group. The results also indicate that there is a positive effect of teaching according to this approach on student achievement, to know the size of the effect, the formula for the directed effect size complementing the statistical significance is applied in light of the values of the t- test.

1. STEM approach has clear efficacy in developing students' innovative thinking skills.
2. STEM approach works to raise students' achievement in mathematics.
3. Teaching with the STEM approach creates an atmosphere of enthusiasm that attracts students to mathematics and improves their motivation for learning, creativity and innovation.
4. Mathematics books should contain attitudes, experiences, and activities that develop the innovative skills of SSC students
5. Holding training programs for teachers to raise awareness of the entrance, its principles and the roll of teachers in it.

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