Effectiveness of STEM-Based Integrated Teaching on Problem-Solving Ability in the Chapter 'Exploring Forces' Among Class VIII Students

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ABSTRACT

The present study aimed to examine the effectiveness of STEM-Based Integrated Teaching on problem-solving ability among Class VIII students in the Science chapter *Exploring Forces*. The study adopted a quasi-experimental pre-test–post-test non-equivalent control group design. A sample of 60 Class VIII students was selected from a secondary school, consisting of 30 students in the experimental group and 30 students in the control group. The experimental group was taught through STEM-Based Integrated Teaching, integrating Science, Technology, Engineering and Mathematics, whereas the control group received conventional instruction. The intervention was implemented over a period of six weeks, comprising 12 instructional sessions. A researcher-developed test was used to assess students' problem-solving ability. The collected data were analysed using mean, standard deviation, paired-samples t-test and independent-samples t-test. The findings revealed a statistically significant improvement in the pre-test and post-test scores of both experimental and control groups. However, the experimental group recorded a higher mean gain score (4.13) than the control group (0.43). The comparison of individual gain scores revealed a statistically significant difference between the two groups ($t = 10.184$, $p < 0.001$), indicating significantly greater improvement among students who received STEM-Based Integrated Teaching. Although the post-test mean difference between the groups was not statistically significant, the gain-score analysis provided evidence in favour of the STEM-based instructional approach. The study highlights the potential of STEM-Based Integrated Teaching in promoting problem-solving ability through interdisciplinary, activity-oriented and application-based Science learning.

Keywords: STEM-Based Integrated Teaching, Problem-Solving Ability, Exploring Forces, Class VIII Students, Science Education.

1.0 INTRODUCTION

Science education plays an important role in developing scientific knowledge, logical thinking, creativity and problem-solving ability among students. It enables learners to understand the natural world through observation, experimentation, investigation and evidence-based reasoning. The teaching of science should not be limited to memorising scientific facts and definitions; rather, it should encourage students to explore concepts, ask questions, identify problems and find suitable solutions through practical experiences.

In the present educational context, there is a growing need to adopt innovative instructional approaches that connect scientific concepts with real-life situations. Traditional teaching methods often emphasise the explanation of concepts and textbook-based learning, providing limited opportunities for students to apply their knowledge to practical problems. Therefore, instructional approaches that promote active participation, experimentation, creativity and interdisciplinary learning are essential for making Science education more meaningful and effective.

STEM-Based Integrated Teaching is an innovative instructional approach that integrates four important disciplines: Science, Technology, Engineering and Mathematics. It provides opportunities for students to understand the connections among these disciplines through practical activities, investigations, designing, experimentation and problem-solving tasks. Instead of learning each subject independently, students apply knowledge and skills from different disciplines to understand real-world situations and develop appropriate solutions.

Science provides the conceptual foundation for understanding natural phenomena, while Technology supports investigation and the use of appropriate tools. Engineering encourages students to design, construct, test and improve solutions, whereas Mathematics helps them measure, calculate, analyse and interpret information. The integration of these disciplines promotes experiential learning and enables students to connect theoretical knowledge with practical applications.

Problem-solving ability is an important component of scientific learning. It refers to the ability of students to identify a problem, understand the given situation, analyse relevant information, select appropriate strategies and arrive at suitable solutions. It involves critical thinking, logical reasoning, decision-making and the application of previously acquired knowledge to unfamiliar situations. Developing problem-solving ability helps students become independent thinkers and prepares them to address challenges encountered in everyday life.

The Class VIII Science Chapter *Exploring Forces* provides meaningful opportunities for integrating STEM-based learning activities. The chapter introduces students to the concept of force and its effects on objects in their surroundings. Students explore how forces can change the state of motion, direction and shape of objects. They also examine different types of forces and their applications in everyday situations. Understanding these concepts requires more than remembering definitions; students need to observe situations, investigate the effects of forces, compare results and apply scientific principles to solve problems.

STEM-Based Integrated Teaching can make the learning of *Exploring Forces* more engaging through activities such as investigating the effects of pushing and pulling, observing friction in different situations, comparing the movement of objects and designing simple models to demonstrate the application of forces. Such activities provide opportunities for students to integrate scientific understanding with mathematical measurement, technological resources and engineering-based design tasks. Through these experiences, students can develop the ability to analyse situations, formulate solutions and evaluate the results of their investigations.

The effectiveness of STEM-based learning depends on meaningful integration of the four disciplines and the active involvement of students in the learning process. Teachers play an important role in planning interdisciplinary activities, providing appropriate learning resources, encouraging collaborative investigation and guiding students towards suitable solutions. Such an approach can transform the Science classroom into an environment where students learn through exploration, experimentation and practical application.

In this context, the present study, entitled **"Effectiveness of STEM-Based Integrated Teaching on Problem-Solving Ability in the Chapter 'Exploring Forces' among Class VIII Students,"** is undertaken to examine the effectiveness of STEM-Based Integrated Teaching in developing problem-solving ability among secondary school students. The study aims to determine whether integrating Science, Technology, Engineering and Mathematics through planned instructional activities can improve students' ability to understand scientific problems, apply relevant concepts and arrive at appropriate solutions while learning the chapter *Exploring Forces*.

2.0 NEED AND SIGNIFICANCE OF THE STUDY

Science education aims not only to provide scientific knowledge but also to develop the ability to observe, investigate, analyse and solve problems. In the present educational context, students need opportunities to connect classroom learning with real-life situations. However, when Science is taught mainly through explanation, memorisation and textbook-based activities, students may find it difficult to apply scientific concepts to practical situations. Therefore, there is a need to adopt innovative instructional approaches that promote active participation, experimentation, critical thinking and problem-solving.

STEM-Based Integrated Teaching provides opportunities to connect Science, Technology, Engineering and Mathematics through meaningful learning experiences. It encourages students to investigate problems, apply interdisciplinary knowledge, design solutions and evaluate outcomes. Such an approach can make Science learning more practical, engaging and application-oriented.

The chapter *Exploring Forces* in Class VIII Science deals with important scientific concepts related to force and its effects on objects. Students are expected to understand how forces influence the movement, direction and shape of objects and recognise the application of forces in everyday life. Learning these concepts requires observation,

experimentation, comparison and logical reasoning. Students need opportunities to investigate different situations and apply scientific principles rather than merely memorising definitions. Hence, the integration of STEM-based activities may provide a meaningful approach to teaching this chapter.

The need and significance of the present study are explained below.

- **Development of Problem-Solving Ability:** Problem-solving ability is an essential skill for scientific learning and everyday life. STEM-Based Integrated Teaching provides opportunities for students to identify problems, analyse situations, select appropriate strategies and develop solutions. Through practical activities related to forces, students can strengthen their ability to apply scientific knowledge to unfamiliar situations.
- **Integration of Science, Technology, Engineering and Mathematics:** The study emphasises the importance of integrating four disciplines into the teaching-learning process. Students can understand scientific principles through experimentation, use technological resources for observation, apply engineering ideas through designing and testing models, and use mathematical skills for measurement and interpretation. This interdisciplinary approach helps students understand the connections between classroom concepts and practical applications.
- **Making Science Learning Practical and Meaningful:** The chapter *Exploring Forces* offers several opportunities for activity-based learning. Activities involving pushing, pulling, friction, movement and changes in the shape of objects can help students understand scientific concepts through direct experiences. STEM-based activities can make the learning process more meaningful by connecting abstract scientific ideas with familiar situations.
- **Promotion of Experiential and Activity-Based Learning:** STEM-Based Integrated Teaching encourages students to learn through observation, experimentation, investigation and practical activities. Students get opportunities to design simple models, test their ideas, observe results and improve their solutions. Such experiences can support a deeper understanding of scientific concepts and encourage active participation.
- **Development of Critical and Logical Thinking:** Solving scientific problems requires students to examine situations, identify relevant information, compare alternatives and make reasoned decisions. STEM-based learning activities can provide opportunities to develop logical reasoning, analytical thinking and the ability to evaluate possible solutions.
- **Encouragement of Creativity and Innovation:** The integration of engineering and technology encourages students to explore different ways of solving problems. Designing and testing simple models related to force and motion can provide opportunities for students to generate ideas, experiment with alternatives and improve their solutions.
- **Improvement of Science Teaching Practices:** The study may encourage Science teachers to move beyond conventional teaching methods and adopt interdisciplinary, activity-oriented instructional approaches. It can provide insights into planning STEM-based activities that connect scientific concepts with practical applications and problem-solving tasks.
- **Significance for Students:** The study may help students develop a better understanding of the chapter *Exploring Forces* through practical learning experiences. It can provide opportunities to apply scientific knowledge, investigate real-life situations and develop problem-solving ability. It may also encourage students to become active and independent participants in the learning process.
- **Significance for Science Teachers:** The study may serve as a useful reference for science teachers in planning and implementing STEM-based instructional activities. It can help teachers integrate different disciplines, organise practical investigations and provide opportunities for students to apply scientific concepts in solving problems.
- **Significance for Schools and Educational Institutions:** The study may encourage schools to provide suitable facilities, materials and learning environments for implementing interdisciplinary and activity-based Science teaching. It may also promote the effective utilisation of available resources for conducting simple STEM-based activities.
- **Significance for Teacher Education:** The study may be useful to teacher education institutions in preparing prospective teachers to adopt innovative instructional strategies. It highlights the importance of

interdisciplinary lesson planning, activity-based teaching, practical investigations and the development of problem-solving ability among school students.

- **Significance for Educational Research:** The study may contribute to the growing body of research on STEM-based integrated teaching in school Science education. It may provide context-specific evidence regarding its effectiveness in developing problem-solving ability among Class VIII students and encourage further research in other Science topics and educational settings.

Overall, the present study is significant because it explores an interdisciplinary instructional approach to make Science learning more practical, meaningful and application-oriented. It seeks to examine whether STEM-Based Integrated Teaching can provide better opportunities for developing problem-solving ability among Class VIII students while learning the chapter *Exploring Forces*.

3.0 THEORETICAL FRAMEWORK

The theoretical framework provides the foundation for understanding how STEM-Based Integrated Teaching can contribute to the development of problem-solving ability among students. The present study is based on the view that meaningful learning takes place when students actively construct knowledge, engage in practical experiences, investigate problems and apply concepts to real-life situations.

STEM-Based Integrated Teaching connects Science, Technology, Engineering and Mathematics through interdisciplinary learning activities. It provides opportunities for students to explore scientific concepts, conduct investigations, design solutions and evaluate results. The present study draws support from four important theoretical perspectives: Constructivist Learning Theory, Experiential Learning Theory, Problem-Based Learning and Polya's Problem-Solving Approach.

3.1 CONSTRUCTIVIST LEARNING THEORY

Constructivist Learning Theory emphasises that learners construct knowledge by connecting new information with their previous knowledge and experiences. According to this perspective, learning is an active process in which students explore ideas, interpret information and develop their own understanding through interaction with the environment.

Piaget highlighted the role of active exploration and cognitive development in knowledge construction, while Vygotsky emphasised the importance of social interaction, collaboration and teacher guidance in learning.

In the present study, students will explore concepts related to force through practical activities and real-life examples. They will investigate the effects of pushing and pulling, observe changes in the movement and shape of objects, and discuss their observations with peers. The teacher will facilitate learning by providing guidance and helping students connect their previous experiences with scientific concepts.

STEM-based activities provide opportunities for students to construct scientific knowledge through observation, experimentation and collaborative learning. This approach can support the development of problem-solving ability by encouraging students to understand situations, identify problems and apply relevant concepts.

3.2 EXPERIENTIAL LEARNING THEORY

Experiential Learning Theory, developed by David A. Kolb, emphasises learning through experience, reflection, conceptual understanding and active experimentation. According to this theory, students develop knowledge by engaging in experiences, reflecting on their observations, forming ideas and testing those ideas in new situations.

The four stages of the experiential learning cycle are:

1. **Concrete Experience:** Students participate in practical activities and experience scientific phenomena.
2. **Reflective Observation:** Students observe the results and reflect on their experiences.
3. **Abstract Conceptualisation:** Students develop scientific explanations and connect observations with theoretical concepts.

4. **Active Experimentation:** Students apply their understanding to new situations and test possible solutions.

In the present study, students will participate in STEM-based activities related to the chapter *Exploring Forces*. For example, they may investigate how pushing and pulling affect the movement of objects, examine the role of friction and compare the movement of objects on different surfaces. They will observe the results, discuss their findings and apply scientific principles to solve related problems.

Thus, experiential learning provides a theoretical foundation for integrating practical activities with scientific concepts and developing students' problem-solving ability.

3.3 PROBLEM-BASED LEARNING

Problem-Based Learning is an instructional approach in which learning begins with a meaningful problem that requires investigation and solution. It encourages students to identify problems, gather relevant information, analyse possible solutions and apply their knowledge to address the given situation.

This approach promotes active participation, independent thinking, collaboration and the practical application of knowledge. The teacher acts as a facilitator by guiding students throughout the problem-solving process.

In the present study, students will be presented with problem situations related to the chapter *Exploring Forces*. For example, they may investigate why an object moves differently on smooth and rough surfaces or how the application of force can change the direction or shape of an object. Students will examine the situations, discuss possible explanations, conduct simple investigations and arrive at suitable solutions.

STEM-Based Integrated Teaching supports this process by allowing students to use scientific principles, technological resources, engineering ideas and mathematical reasoning while addressing problems. Therefore, Problem-Based Learning provides an important foundation for developing problem-solving ability through interdisciplinary activities.

3.4 POLYA'S PROBLEM-SOLVING APPROACH

George Polya proposed a systematic approach to problem-solving that helps learners understand and solve problems logically. His approach consists of four important stages:

1. **Understanding the Problem:** Identifying the problem, understanding the given information and recognising what needs to be solved.

2. **Devising a Plan:** Selecting appropriate strategies, scientific concepts and methods to solve the problem.

3. **Carrying Out the Plan:** Implementing the selected strategy through calculations, experiments, observations or practical activities.

4. **Looking Back:** Reviewing the solution, checking the results and considering whether the method used was appropriate.

In the present study, these stages will guide students in solving problems related to force and its effects. Students will identify the given problem, select suitable scientific principles, conduct relevant investigations and evaluate their findings.

For example, when investigating the movement of an object on different surfaces, students will identify the factors affecting its movement, plan an investigation, observe and compare the results, and evaluate their conclusions. This systematic process can help students develop organised and logical approaches to solving scientific problems.

3.5 THEORETICAL FOUNDATION OF STEM-BASED INTEGRATED TEACHING

STEM-Based Integrated Teaching is supported by the integration of knowledge and skills from four disciplines: Science, Technology, Engineering and Mathematics. Each discipline contributes to the development of students' ability to understand and solve practical problems.

The integration of these disciplines in the present study is explained below:

- **Science:** Students will understand the scientific concepts of force, its effects, different types of forces and their applications in everyday situations.
- **Technology:** Students will use suitable technological resources, such as instructional videos, presentations and digital simulations, to observe and understand the effects of forces.
- **Engineering:** Students will participate in designing, constructing, testing and improving simple models related to the application of forces.
- **Mathematics:** Students will use measurement, comparison, calculation and interpretation of numerical information during practical investigations.

The integration of these four disciplines will provide opportunities for students to apply scientific knowledge to practical situations and develop appropriate solutions through investigation and experimentation.

3.6 CONCEPTUAL FRAMEWORK

The conceptual framework of the present study illustrates the relationship between STEM-Based Integrated Teaching and the development of problem-solving ability among Class VIII students. The components are summarised in Table 1.

Table 1: Conceptual framework of the study.

Component	Description
Independent Variable	STEM-Based Integrated Teaching involving Science, Technology, Engineering and Mathematics.
Learning Experiences	Observation, experimentation, investigation, designing, construction, measurement, discussion and evaluation.
Problem-Solving Process	Identifying problems, analysing situations, planning solutions, implementing strategies and evaluating results.
Dependent Variable	Problem-Solving Ability among Class VIII students in the chapter *Exploring Forces*, assessed through a researcher-developed Problem-Solving Ability Test.

The present study will examine whether the learning experiences provided through STEM-Based Integrated Teaching led to a measurable improvement in students' problem-solving ability in the chapter *Exploring Forces*. The effectiveness of the instructional intervention will be determined through the collection and statistical analysis of empirical data.

4.0 LITERATURE REVIEW

A review of related literature provides a foundation for understanding previous research, identifying major findings and recognising areas that require further investigation. The present study focuses on the effectiveness of STEM-Based Integrated Teaching on problem-solving ability in the chapter *Exploring Forces* among Class VIII students. Therefore, the review considers studies related to integrated STEM education, problem-solving skills and STEM-based instructional practices in school education.

4.1 Studies Related to Integrated Stem Education

Le, Nguyen and Nguyen (2023) conducted a systematic review titled *Integrated STEM Approaches and Associated Outcomes of K-12 Student Learning: A Systematic Review*. The researchers reviewed 47 studies to examine the relationship between integrated STEM approaches and students' learning outcomes at the K–12 level. The findings indicated that different STEM approaches contributed to different learning outcomes. STEM project-based learning activities in science were associated with improvements in learning achievement and higher-order thinking skills. The study highlighted the importance of selecting appropriate instructional approaches according to the intended learning outcomes.

McLure, Tang and Williams (2022) conducted a systematic literature review titled *What Do Integrated STEM Projects Look Like in Middle School and High School Classrooms? A Systematic Literature Review of Empirical Studies of iSTEM*

Projects. The researchers examined 35 peer-reviewed publications related to integrated STEM projects in middle and high school classrooms. The findings revealed that Science and Engineering, particularly Physics, were among the most frequently integrated disciplines. The review also highlighted the importance of providing students with authentic opportunities to solve real-world problems. The researchers identified a need for clearer documentation of how teachers and students integrate STEM knowledge and skills during classroom activities.

4.2 Studies Related to Stem Instructional Design

Halawa, Lin and Hsu (2024) conducted a systematic literature review titled *Exploring Instructional Design in K-12 STEM Education: A Systematic Literature Review*. The study analysed 229 research articles published between 2012 and 2021. The researchers examined different instructional designs, including design-based learning, inquiry-based learning, project-based learning and problem-based learning. The findings revealed that design-based learning was the most frequently adopted instructional approach, followed by inquiry-based, project-based and problem-based learning. The study emphasised the importance of systematic instructional planning and the alignment of learning activities with educational objectives.

4.3 Studies Related to Stem and Problem-Solving Ability

Öndeş (2025) conducted a meta-analysis titled *Effects of STEM Practices on Students' Problem-Solving Skills: A Meta-Analysis*. The study examined 25 individual research studies to determine the effect of STEM practices on students' problem-solving skills. The findings indicated an overall positive effect of STEM practices on problem-solving skills. The analysis also revealed variations in the effects according to educational level, instructional approach, subject area and intervention duration. Experiential learning and design-based approaches demonstrated particularly strong effects in the reviewed studies. The findings support the importance of providing students with practical and interdisciplinary learning experiences to develop problem-solving ability.

Chen et al. (2026) conducted a meta-analysis titled *The Effects of Integrated STEM Education on K-12 Students' Achievements: A Meta-Analysis*. The researchers synthesised evidence from 124 studies published between 2010 and 2022. The study examined knowledge acquisition, cognitive skills, problem-solving task performance and students' perceptions. The findings indicated that integrated STEM programmes supported students' knowledge acquisition and cognitive development. Programmes combining STEM integration with additional teaching and learning strategies demonstrated a medium effect on problem-solving task performance. The researchers also highlighted the influence of task type and programme duration on learning outcomes. The study emphasised the importance of well-designed inquiry-based and engineering design activities in integrated STEM education.

4.4 Summary of the Review of Related Literature

The review of the above studies indicates that integrated STEM education has become an important instructional approach in school education. The reviewed literature highlights the value of connecting Science, Technology, Engineering and Mathematics through practical activities, investigation, experimentation, project work and design-based learning.

The studies also indicate that STEM-based instructional approaches can provide opportunities for students to develop problem-solving skills by identifying problems, analysing situations, applying interdisciplinary knowledge, designing solutions and evaluating results. The findings emphasise that the effectiveness of STEM education depends on appropriate instructional planning, meaningful integration of disciplines and the nature of learning activities provided to students.

Furthermore, the reviewed studies highlight the importance of experiential, inquiry-based and design-based learning in making scientific concepts more meaningful and application-oriented. These approaches are particularly relevant to school Science education, where students need opportunities to connect theoretical knowledge with practical situations.

4.5 Research Gap

Although several studies have examined the effectiveness of integrated STEM education in developing students' learning outcomes and problem-solving skills, certain areas require further investigation. Many existing studies have focused on

general STEM competencies, academic achievement, higher-order thinking skills and broad problem-solving performance. There is a need for further context-specific research examining the development of problem-solving ability through STEM-based instruction in individual Science chapters at the middle-school level.

The chapter *Exploring Forces* provides opportunities for students to investigate the effects of force, examine different situations involving movement and friction, conduct simple experiments and apply scientific concepts to practical problems. Integrating Science, Technology, Engineering and Mathematics into the teaching of this chapter may provide meaningful opportunities for students to identify problems, analyse situations, plan solutions and evaluate their results.

Therefore, the present study proposes to investigate the effectiveness of STEM-Based Integrated Teaching on problem-solving ability in the chapter *Exploring Forces* among Class VIII students. The study aims to contribute context-specific evidence regarding the application of integrated STEM instruction in middle-school Science education, with particular emphasis on problem-solving ability as the dependent variable.

5.0 OBJECTIVES OF THE STUDY

The present study was undertaken with the following objectives:

1. To assess the pre-test level of problem-solving ability among Class VIII students in the chapter *Exploring Forces* in the experimental and control groups.
2. To develop and implement a STEM-Based Integrated Teaching Programme for teaching the chapter *Exploring Forces* to Class VIII students.
3. To assess the post-test level of problem-solving ability among students in the experimental and control groups after the instructional intervention.
4. To determine the difference between the pre-test and post-test problem-solving ability scores of students in the experimental group.
5. To determine the difference between the pre-test and post-test problem-solving ability scores of students in the control group.
6. To compare the post-test scores of problem-solving abilities among students in the experimental and control groups.
7. To examine the effectiveness of STEM-Based Integrated Teaching in developing problem-solving ability among Class VIII students in the chapter *Exploring Forces*.

6.0 HYPOTHESES OF THE STUDY

The following null hypotheses are formulated for the present study:

H_o1: There is no significant difference between the pre-test and post-test problem-solving ability scores of students in the experimental group.

H_o2: There is no significant difference between the pre-test and post-test problem-solving ability scores of students in the control group.

H_o3: There is no significant difference between the pre-test problem-solving ability scores of students in the experimental and control groups.

H_o4: There is no significant difference between the post-test problem-solving ability scores of students in the experimental and control groups.

7.0 RESEARCH METHODOLOGY

Research methodology refers to the systematic procedure adopted by the researcher to conduct the study, collect relevant data and analyse the findings. The present study aims to investigate the effectiveness of STEM-Based Integrated

Teaching on problem-solving ability in the chapter *Exploring Forces* among Class VIII students. The methodology includes the research design, population, sample, sampling technique, variables, research tool, development of the instructional programme, procedure of data collection and statistical techniques.

7.1 Research Design

The present study will adopt a **quasi-experimental pre-test–post-test non-equivalent control group design**. This design is suitable for examining the effectiveness of STEM-Based Integrated Teaching by comparing the problem-solving ability of students in the experimental and control groups.

The experimental group will be taught the chapter *Exploring Forces* through STEM-Based Integrated Teaching, whereas the control group will receive instruction through the conventional teaching method. Both groups will be administered a pre-test before the instructional intervention and a post-test after its completion.

7.2 Population of the Study

The population of the present study will consist of Class VIII students studying Science in secondary schools following the Karnataka State Board curriculum.

7.3 Sample of the Study

The present study will adopt the intact classroom selection technique. Two existing Class VIII classroom groups from one secondary school will be selected for the study. One intact classroom consisting of 30 students will be designated as the experimental group and the other intact classroom consisting of 30 students will be designated as the control group.

Individual students will not be randomly assigned to the groups, and the existing classroom arrangements will be maintained.

7.4 Variables of the Study

The following variables will be considered in the present study:

Independent Variable: STEM-Based Integrated Teaching.

Dependent Variable: Problem-Solving Ability among Class VIII students in the chapter *Exploring Forces*.

7.5 Research Tool

The researcher will develop a **Problem-Solving Ability Test** based on the prescribed Class VIII Science chapter *Exploring Forces* of the Karnataka State Board curriculum.

The test will be designed to assess students' ability to:

- Identify and understand scientific problems related to force.
- Analyse situations involving the effects of forces.
- Select appropriate scientific concepts and strategies to solve problems.
- Apply scientific knowledge to practical situations.
- Interpret experimental observations and arrive at suitable solutions.
- Evaluate solutions and draw appropriate conclusions.

The researcher will establish the content validity of the test by reviewing its items in relation to the prescribed syllabus, learning objectives and dimensions of problem-solving ability. A pilot study will then be conducted to examine the clarity, suitability and reliability of the test before its final administration.

7.6 Development of the STEM-Based Integrated Teaching Programme

The researcher will develop an instructional programme based on the integration of Science, Technology, Engineering and Mathematics for teaching the chapter *Exploring Forces*.

The programme will incorporate the following components:

- **Science Integration:** Students will explore the concepts of force, its effects, different types of forces and their applications in everyday situations through observation and experimentation.
- **Technology Integration:** Students will use appropriate technological resources, such as instructional videos, presentations, animations and digital simulations, to understand scientific concepts and observe the effects of forces.
- **Engineering Integration:** Students will participate in designing, constructing, testing and improving simple models related to the application of forces. These activities will provide opportunities to identify problems and develop practical solutions.
- **Mathematics Integration:** Students will apply mathematical skills such as measurement, calculation, comparison, data recording and interpretation during practical investigations.

The integrated activities will be designed to provide opportunities for students to identify problems, analyse situations, plan solutions, implement strategies and evaluate results.

7.7 Procedure for Data Collection

The data collection procedure will be carried out in the following stages:

- **Selection of the Sample:** The researcher will select the school(s) and Class VIII students for the study.
- **Formation of Groups:** The selected students will be organised into experimental and control groups based on the available classroom arrangements.
- **Administration of Pre-test:** A pre-test will be administered to both groups to assess their initial problem-solving ability in the chapter *Exploring Forces*.
- **Implementation of the Intervention:** The experimental group will be taught through STEM-Based Integrated Teaching, while the control group will receive conventional instruction.
- **Administration of Post-test:** After completing the instructional programme, the post-test will be administered to both groups to assess their problem-solving ability.
- **Collection of Data:** The answer scripts will be evaluated according to the predetermined scoring procedure.
- **Analysis and Interpretation:** The collected data will be tabulated, analysed and interpreted using appropriate statistical techniques.

7.8 Duration of the Intervention

The STEM-Based Integrated Teaching Programme will be implemented over a period of six weeks, with two instructional sessions per week, resulting in a total of 12 instructional sessions. The experimental group will receive STEM-based instruction, while the control group will receive conventional instruction covering the same chapter and learning objectives.

7.9 Statistical Techniques

The collected data will be analysed using suitable descriptive and inferential statistical techniques.

The following statistical techniques will be considered:

- **Mean:** To determine the average pre-test and post-test scores of the experimental and control groups.

- **Standard Deviation:** To determine the variability in students' problem-solving ability scores.
- **Paired-Samples t-test:** To examine the difference between pre-test and post-test scores within each group.
- **Independent-Samples t-test:** To compare the pre-test and post-test scores of the experimental and control groups.
- The level of significance will be fixed at 0.05 for testing the null hypotheses.

7.10 Ethical Considerations

The researcher will obtain the necessary permission from the concerned school authorities before conducting the study. Appropriate arrangements will be made to ensure that students receive equal learning opportunities. The confidentiality of the collected data will be maintained, and the instructional activities will be conducted without adversely affecting the regular academic schedule.

8.0 IMPLEMENTATION OF THE STEM-BASED INTEGRATED TEACHING

The STEM-Based Integrated Teaching Programme will be implemented to teach the chapter *Exploring Forces* in Science to Class VIII students. The programme will be conducted over a period of six weeks, with two instructional sessions per week, resulting in a total of 12 sessions.

The experimental group, consisting of 30 students, will receive instruction through STEM-Based Integrated Teaching, whereas the control group, consisting of 30 students, will be taught through the conventional teaching method.

The instructional programme will integrate Science, Technology, Engineering and Mathematics through practical activities, investigations, problem-solving tasks and collaborative learning experiences. The implementation will focus on developing students' ability to identify problems, analyse situations, plan solutions, apply scientific concepts and evaluate results.

8.1 Science-Based Learning Activities

The Science component will focus on developing an understanding of the concepts presented in the chapter *Exploring Forces*. Students will explore the effects of forces through observation, demonstration and experimentation.

The activities will include:

- Investigating the effects of pushing and pulling on objects.
- Observing changes in the motion, direction and shape of objects due to force.
- Exploring different types of forces through practical examples.
- Investigating the effects of friction in everyday situations.
- Identifying the role of forces in different real-life situations.
- Analysing scientific problems related to the application of forces.

These activities will help students understand scientific principles and apply them to practical situations.

8.2 Technology-Based Learning Activities

Technology will be integrated into the teaching-learning process through suitable digital resources and instructional materials. Students will be provided with opportunities to observe scientific phenomena through visual and interactive resources.

The activities will include:

- Viewing short instructional videos related to force and its effects.

- Observing animations and digital simulations demonstrating different forces.
- Using digital presentations to understand scientific concepts.
- Observing and analysing the effects of forces through visual demonstrations.
- Using available digital resources to investigate and discuss scientific problems.

These activities will support students in understanding concepts that may be difficult to observe directly.

8.3 Engineering-Based Learning Activities

The Engineering component will provide opportunities for students to apply scientific knowledge through designing, constructing, testing and improving simple models. Students will work individually or in groups to develop solutions to practical problems related to forces.

The activities will include:

- Designing a simple model to demonstrate the application of force.
- Constructing a simple moving model using safe and locally available materials.
- Investigating how different surfaces influence the movement of objects.
- Testing and improving a model based on its performance.
- Identifying problems in a design and suggesting suitable improvements.

These activities will encourage students to apply scientific concepts and develop systematic approaches to solving problems.

8.4 Mathematics-Based Learning Activities

Mathematics will be integrated through measurement, calculation, comparison and interpretation of observations obtained during practical activities.

The activities will include:

- Measuring and comparing distances travelled by objects.
- Recording observations in tables.
- Comparing the movement of objects under different conditions.
- Calculating differences in measured values.
- Representing observations through simple charts and graphs.
- Interpreting numerical information to arrive at conclusions.

These activities will help students apply mathematical reasoning while investigating scientific phenomena.

8.5 Development of Problem-Solving Ability

Problem-solving ability will be the central focus of the STEM-Based Integrated Teaching Programme. Students will be encouraged to follow a systematic approach while addressing scientific problems.

The following stages will be incorporated into classroom activities:

- **Identifying the Problem:** Students will recognise and clearly define the scientific problem presented.
- **Analysing the Problem:** Students will examine the given situation and identify relevant scientific concepts and information.

- **Planning the Solution:** Students will suggest possible methods and select suitable strategies to solve the problem.
- **Implementing the Solution:** Students will conduct investigations, perform activities or construct simple models to test their proposed solutions.
- **Evaluating the Solution:** Students will observe the results, examine the effectiveness of their solutions and suggest necessary improvements.

8.6 Session-Wise Implementation Plan

The STEM-Based Integrated Teaching Programme will be implemented through 12 instructional sessions over six weeks. The proposed session-wise plan is presented in Table 2.

Table 2: Session-wise implementation plan.

Week	Session	Topic / Activity	Integrated STEM Components
1	1	Introduction to Force: Pushing and Pulling	Science – Understanding force; Technology – Visual demonstrations; Mathematics – Comparing observations.
1	2	Effects of Force on Objects	Science – Changes in motion, direction and shape; Engineering – Demonstration models; Mathematics – Measurement.
2	3	Contact and Non-Contact Forces	Science – Exploring different forces; Technology – Animations and demonstrations; Mathematics – Classification and comparison.
2	4	Investigating Friction	Science – Understanding friction; Engineering – Comparing different surfaces; Mathematics – Recording and interpreting observations.
3	5	Force and Motion in Everyday Situations	Science – Analysing motion; Technology – Video-based investigation; Mathematics – Measuring and comparing distances.
3	6	Problem-Solving Activities Related to Forces	Science – Applying force concepts; Engineering – Designing simple solutions; Mathematics – Analysing results.
4	7	Exploring the Effects of Different Forces	Science – Investigating force-related situations; Technology – Digital simulations; Mathematics – Comparing observations.
4	8	Engineering Design Activity Related to Forces	Engineering – Designing and constructing a simple moving model; Science – Applying force concepts; Mathematics – Measurement.
5	9	Testing and Improving Models	Engineering – Testing and improving designs; Science – Observing the effects of forces; Mathematics – Recording results.
5	10	STEM-Based Real-Life Problem-Solving Tasks	Integration of all four disciplines through practical problem-solving situations.
6	11	Collaborative STEM Challenges	Group investigations, analysis of problems, planning solutions and evaluating results.
6	12	Consolidation and Application of Concepts	Integrated revision, application-based questions and problem-solving exercises.

8.7 Role of the Teacher

The teacher will act as a facilitator and guide throughout the implementation of the STEM-Based Integrated Teaching Programme. The teacher will plan interdisciplinary activities, provide appropriate learning resources, organise practical investigations and encourage students to participate actively in problem-solving tasks.

The teacher will also guide students in identifying problems, selecting suitable strategies, conducting investigations and evaluating their solutions. Appropriate feedback will be provided to strengthen students' understanding and problem-solving ability.

8.8 Role of Students

Students will actively participate in the STEM-based learning activities by observing scientific phenomena, conducting experiments, discussing problems, designing simple models and interpreting results. They will be encouraged to work collaboratively, share ideas, apply interdisciplinary knowledge and develop appropriate solutions to the problems presented during classroom activities.

8.9 Instruction for the Control Group

The control group, consisting of 30 students, will be taught the same chapter, *Exploring Forces*, through the conventional teaching method. The teacher will explain the concepts using textbooks, classroom explanations, diagrams, demonstrations and relevant examples.

The control group will cover the same instructional content and learning objectives as the experimental group. The duration of instruction will also be kept comparable to ensure a meaningful comparison between the two groups.

8.10 Evaluation of the Implementation

At the end of the six-week instructional programme, both the experimental and control groups will be administered the post-test to assess their problem-solving ability in the chapter *Exploring Forces*. The post-test scores will be compared with the pre-test scores to determine the changes in students' problem-solving ability and examine the effectiveness of STEM-Based Integrated Teaching.

9.0 ANALYSIS AND INTERPRETATION

Hypothesis 1: There is no significant difference between the pre-test and post-test scores of problem-solving abilities among students in the experimental group.

Table 3: Comparison of Pre-Test and Post-Test Scores of the Experimental Group

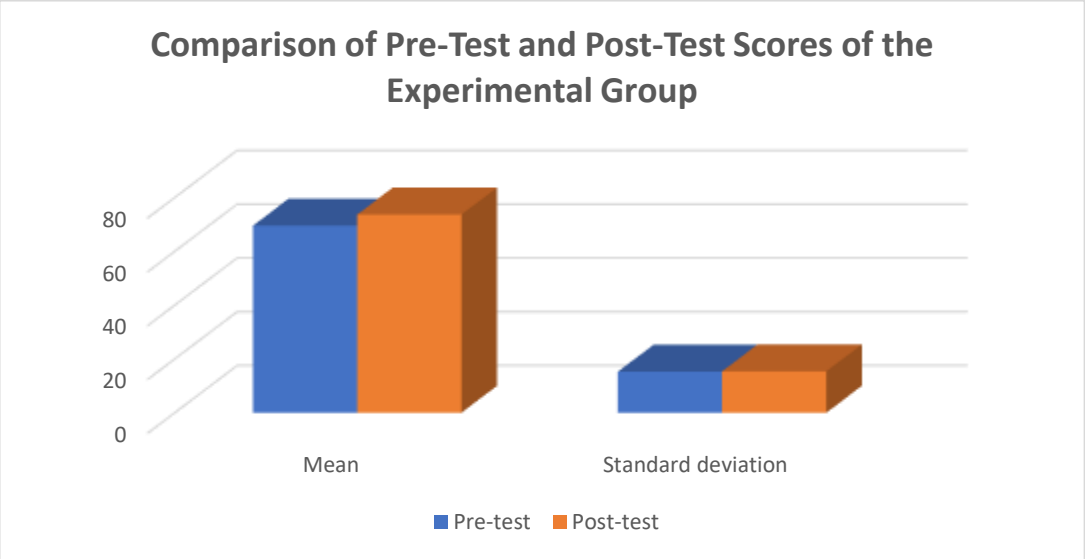
Experimental group	N	Mean	Standard deviation	t-value	p-value / significance	Decision
Pre-test	30	69.53	15.24	13.852	0.0000000000021	Significant
Post-test	30	73.67	15.38			

Table 3 presents the comparison of pre-test and post-test scores of problem-solving abilities among students in the experimental group. The mean pre-test score was 69.53, with a standard deviation of 15.24, whereas the mean post-test score was 73.67, with a standard deviation of 15.38.

The calculated paired-samples t-value was 13.852, which is statistically significant at the 0.001 level ($p < 0.001$). The mean score increased by 4.13 points from pre-test to post-test, indicating a significant improvement in students' problem-solving ability.

Therefore, the null hypothesis is rejected. It can be concluded that there is a statistically significant difference between the pre-test and post-test scores of problem-solving abilities among students in the experimental group. The findings indicate that students demonstrated improved problem-solving ability after receiving STEM-Based Integrated Teaching.

Figure 1: Comparison of Pre-Test and Post-Test Scores of the Experimental Group



Hypothesis 2: There is no significant difference between the pre-test and post-test scores of problem-solving abilities among students in the control group.

Table 4: Comparison of Pre-Test and Post-Test Scores of the Control Group

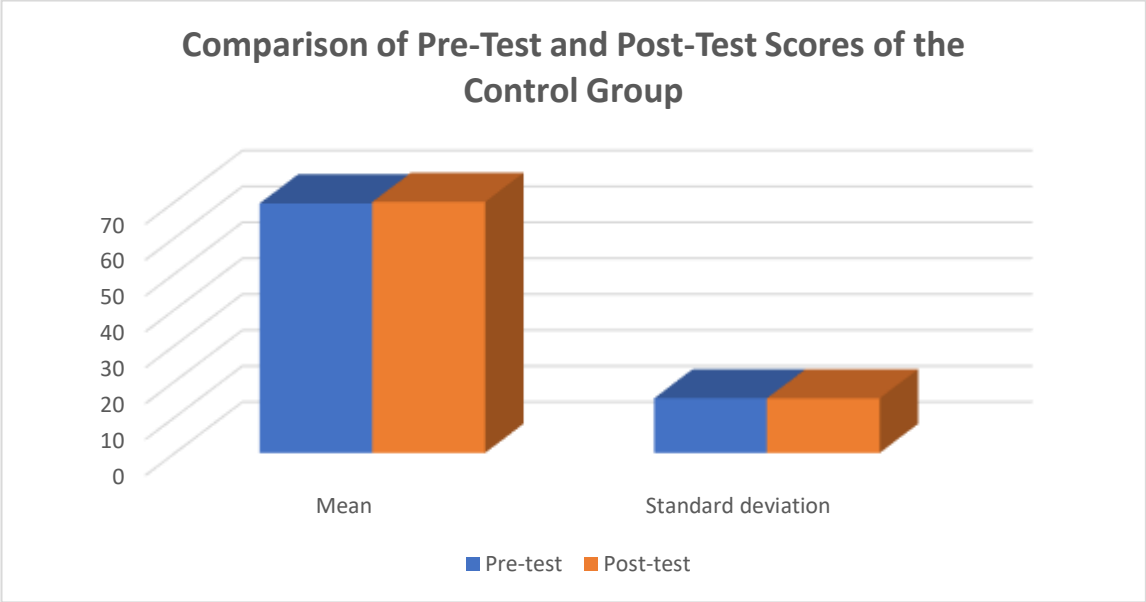
Control group	N	Mean	Standard deviation	t-value	p-value / significance	Decision
Pre-test	30	69.47	15.22	2.091	0.045	Significant
Post-test	30	69.90	15.20			

Table 4 presents the comparison of pre-test and post-test scores of problem-solving abilities among students in the control group. The mean pre-test score was 69.47, with a standard deviation of 15.22, whereas the mean post-test score was 69.90, with a standard deviation of 15.20.

The calculated t-value was 2.091, which is statistically significant at the 0.05 level ($p = 0.045$). The mean score increased by 0.43 points from pre-test to post-test, indicating a small but statistically significant improvement in problem-solving ability among the students.

Therefore, the null hypothesis is rejected. It can be concluded that there is a statistically significant difference between the pre-test and post-test scores of problem-solving abilities among students in the control group. However, the improvement in the control group was comparatively small.

Figure 2: Comparison of Pre-Test and Post-Test Scores of the Control Group



Hypothesis 3: There is no significant difference between the pre-test scores of problem-solving abilities among students in the experimental and control groups.

Table 5: Comparison of the Pre-Test Scores of Students in the Experimental and Control Groups

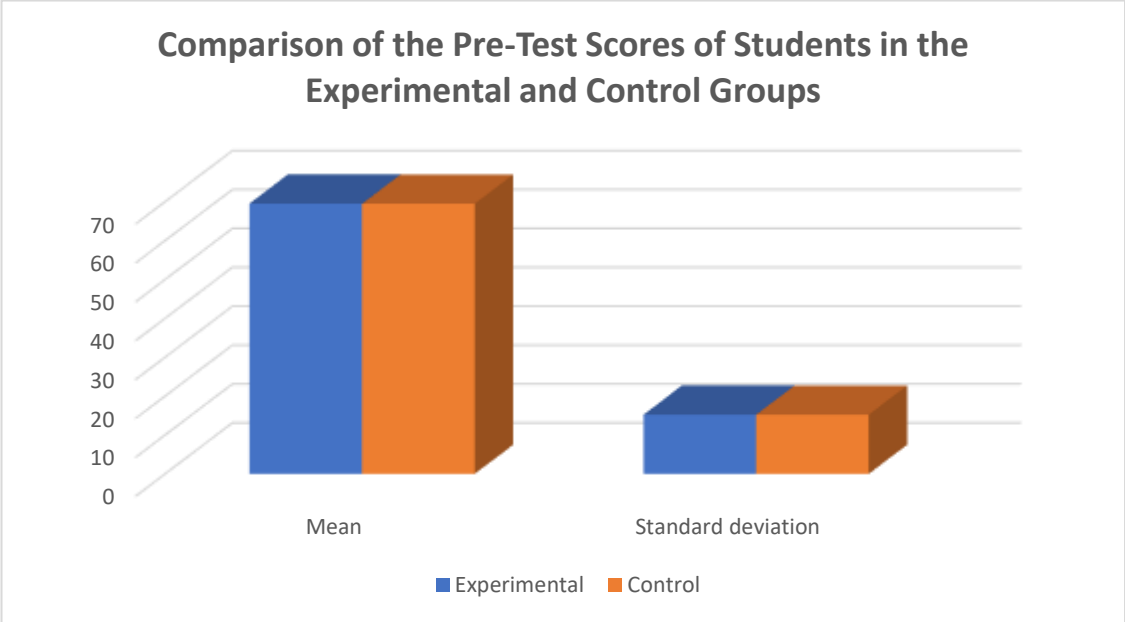
Group	N	Mean	Standard deviation	t-value	p-value / significance	Decision
Experimental	30	69.53	15.24	0.017	0.987	Not Significant
Control	30	69.47	15.22			

Table 5 presents the comparison of pre-test scores of problem-solving abilities among students in the experimental and control groups. The experimental group obtained a mean score of 69.53 with a standard deviation of 15.24, whereas the control group obtained a mean score of 69.47 with a standard deviation of 15.22.

The calculated t-value was 0.017, which is not statistically significant at the 0.05 level ($p = 0.987$). This indicates that there was no significant difference between the pre-test scores of the two groups.

Therefore, the null hypothesis is not rejected. It can be concluded that the experimental and control groups had comparable levels of problem-solving ability before the implementation of STEM-Based Integrated Teaching.

Figure 3: Comparison of the Pre-Test Scores of Students in the Experimental and Control Groups



Hypothesis 4: There is no significant difference between the post-test scores of problem-solving abilities among students in the experimental and control groups.

Table 6: Comparison of the Post-Test Scores of Students in the Experimental and Control Groups

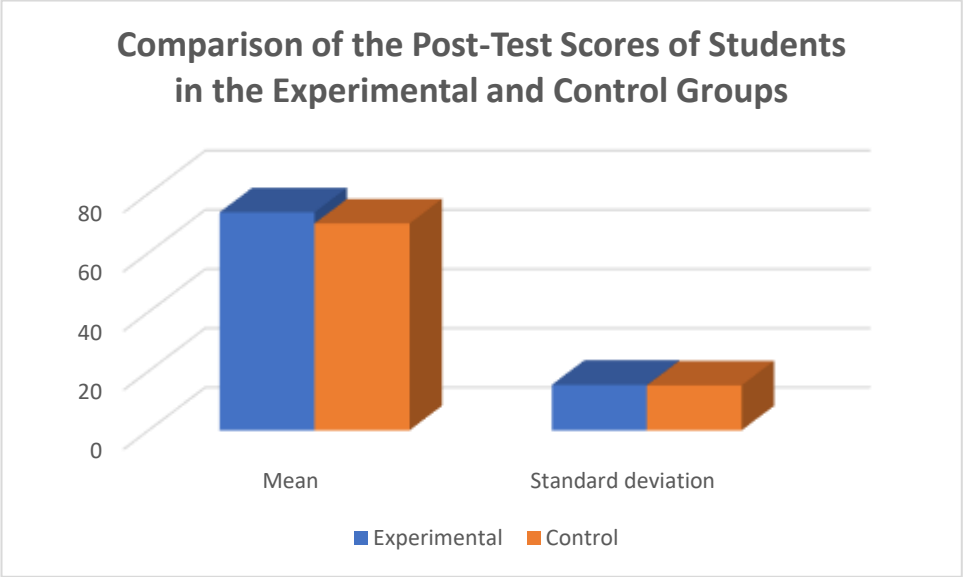
Group	N	Mean	Standard deviation	t-value	p-value / significance	Decision
Experimental	30	73.67	15.38	0.954	0.344	Not Significant
Control	30	69.90	15.20			

Table 6 presents the comparison of post-test scores of problem-solving abilities among students in the experimental and control groups. The experimental group obtained a mean score of 73.67 with a standard deviation of 15.38, whereas the control group obtained a mean score of 69.90 with a standard deviation of 15.20.

The calculated t-value was 0.954, which is not statistically significant at the 0.05 level ($p = 0.344$). Although the experimental group obtained a higher mean score than the control group, the difference was not statistically significant.

Therefore, the null hypothesis is not rejected. It can be concluded that there is no statistically significant difference between the post-test scores of problem-solving abilities among students in the experimental and control groups at the 0.05 significance level.

Figure 4: Comparison of the Post-Test Scores of Students in the Experimental and Control Groups



10.0 FINDINGS OF THE STUDY

1. A statistically significant difference was found between the pre-test and post-test problem-solving ability scores of students in the experimental group. Students demonstrated improved problem-solving ability after receiving instruction through STEM-Based Integrated Teaching.

2. A statistically significant difference was found between the pre-test and post-test problem-solving ability scores of students in the control group. However, the improvement in their mean scores was comparatively small.

3. There was no statistically significant difference found between the pre-test problem-solving ability scores of students in the experimental and control groups, indicating that both groups had comparable initial levels of problem-solving ability.

4. There was no statistically significant difference found between the post-test problem-solving ability scores of students in the experimental and control groups, although the experimental group obtained a higher mean score than the control group.

5. The experimental group showed a greater improvement in problem-solving ability than the control group. The experimental group recorded a mean gain of 4.13, whereas the control group recorded a mean gain of 0.43, indicating a difference of 3.70 points in mean improvement between the two groups.

11.0 DISCUSSION OF THE FINDINGS

The present study was conducted to examine the effectiveness of STEM-Based Integrated Teaching on problem-solving ability among Class VIII students in the Science chapter *Exploring Forces*. The findings revealed that students in the experimental group demonstrated a statistically significant improvement in problem-solving ability after participating in STEM-Based Integrated Teaching. The mean score increased from 69.53 in the pre-test to 73.67 in the post-test, showing a mean improvement of 4.13 points. This indicates that integrating Science, Technology, Engineering and Mathematics into classroom instruction can provide opportunities for students to understand scientific concepts, engage in practical activities and develop problem-solving skills.

The analysis of the control group also revealed a statistically significant difference between pre-test and post-test scores. However, the mean improvement was only 0.43 points, which was considerably lower than that of the experimental group. This suggests that conventional teaching was associated with a smaller improvement in students' problem-solving ability during the study period.

The comparison of pre-test scores showed no statistically significant difference between the experimental and control groups ($p = 0.987$). This indicates that both groups had comparable initial levels of problem-solving ability before the

intervention. Therefore, the improvement observed in the experimental group can be considered in relation to its participation in the STEM-Based Integrated Teaching programme, while recognising the limitations of the quasi-experimental design.

The comparison of post-test scores revealed that the experimental group obtained a higher mean score (73.67) than the control group (69.90). The mean difference was 3.77 points. However, this difference was not statistically significant ($p = 0.344$). Hence, the post-test comparison alone does not provide sufficient statistical evidence to establish the superiority of STEM-Based Integrated Teaching over conventional teaching.

Nevertheless, the difference in mean gain scores provides a useful descriptive indication. The experimental group recorded a mean gain of 4.13 points, whereas the control group recorded a mean gain of 0.43 points, resulting in a difference of 3.70 points in improvement. This suggests a comparatively greater improvement in the experimental group.

Overall, the findings suggest that STEM-Based Integrated Teaching has potential for improving problem-solving ability among Class VIII students in the context of the chapter *Exploring Forces*. Integrating practical investigations, technological resources, engineering design activities and mathematical reasoning may encourage students to identify problems, analyse situations, plan solutions and evaluate outcomes. The study highlights the educational value of integrating STEM disciplines into science teaching and the need for further research with larger samples and appropriate statistical analysis to establish its effectiveness more conclusively.

12.0 EDUCATIONAL IMPLICATIONS

The findings of the present study have several implications for science teaching and learning, particularly in developing problem-solving ability among secondary school students. The study highlights the importance of integrating Science, Technology, Engineering and Mathematics through meaningful classroom activities. The following are the major educational implications:

- **Promotion of STEM-Based Teaching:** Science teachers should incorporate STEM-Based Integrated Teaching into classroom instruction to connect scientific concepts with real-life situations and practical applications.
- **Development of Problem-Solving Ability:** Teachers should provide opportunities for students to identify problems, analyse situations, plan solutions, implement strategies and evaluate outcomes through structured learning activities.
- **Integration of Four STEM Disciplines:** Science teaching should integrate scientific concepts with technological resources, engineering design activities and mathematical reasoning to promote meaningful and interdisciplinary learning.
- **Emphasis on Activity-Based Learning:** Teachers should organise experiments, investigations, model-making activities and problem-solving tasks that actively involve students in the learning process.
- **Use of Technology in Science Education:** Digital presentations, educational videos, animations and simulations may be used to make abstract scientific concepts more understandable and interesting.
- **Promotion of Critical and Creative Thinking:** STEM-based activities should encourage students to think independently, explore alternative solutions, make decisions and apply their knowledge to unfamiliar situations.
- **Collaborative Learning:** Group-based STEM activities should be encouraged to develop cooperation, communication, teamwork and shared responsibility among students.
- **Improvement of Science Curriculum:** Curriculum developers should provide scope for interdisciplinary activities, practical investigations and real-life problem-solving tasks in science textbooks and learning materials.

- **Professional Development of Teachers:** Teacher education institutions and educational authorities should organise workshops and training programmes to equip teachers with the knowledge and skills required to plan and implement STEM-based lessons.

- **Development of Appropriate Assessment Strategies:** Teachers should use performance-based assessments, project work, practical tasks and problem-solving tests to evaluate students' application of knowledge rather than depending exclusively on written examinations.

- **Provision of Learning Resources:** Schools should provide appropriate laboratory facilities, low-cost materials, technological resources and activity-based learning environments to support STEM education.

- **Encouragement of Experiential Learning:** Students should be encouraged to learn through observation, experimentation, designing, testing and improving simple models, thereby connecting classroom learning with everyday experiences.

13.0 SUGGESTIONS FOR FURTHER RESEARCH

The present study was limited to examining the effectiveness of STEM-Based Integrated Teaching on problem-solving ability among Class VIII students in the Science chapter *Exploring Forces*. Further research can be undertaken in the following areas:

- Similar studies may be conducted with a larger sample drawn from different schools to improve the generalisability of the findings.

- Further studies may be conducted among students of different classes and educational levels to examine the effectiveness of STEM-Based Integrated Teaching across age groups.

- The effectiveness of STEM-Based Integrated Teaching may be investigated in different Science chapters, such as Light, Sound, Electricity and other topics prescribed in the school curriculum.

- Comparative studies may be conducted to examine the effectiveness of STEM-Based Integrated Teaching and other innovative teaching strategies, such as Project-Based Learning, Inquiry-Based Learning and Problem-Based Learning.

- Further research may examine the effectiveness of STEM-Based Integrated Teaching on other learning outcomes, such as academic achievement, conceptual understanding, scientific attitude, creativity and critical thinking.

- Studies may be conducted to examine the effectiveness of STEM-Based Integrated Teaching among students from rural and urban schools.

- Further research may investigate gender-based differences in the development of problem-solving ability through STEM-based instructional approaches.

- Longitudinal studies may be undertaken to examine the long-term impact of STEM-Based Integrated Teaching on students' problem-solving ability and application of scientific knowledge.

- Further studies may explore the effectiveness of technology-supported STEM activities, including digital simulations, educational applications and interactive learning resources.

- Research may be conducted to identify the challenges faced by Science teachers in implementing STEM-Based Integrated Teaching in schools with different levels of infrastructure and learning resources.

- Similar studies may be conducted to examine the effectiveness of STEM-Based Integrated Teaching in other subject areas, such as Mathematics, Social Science and Environmental Science.

- Further research may be undertaken to develop and validate standardised tools for assessing problem-solving ability among secondary school students in different subject areas.

14.0 CONCLUSION

The present study was undertaken to examine the effectiveness of STEM-Based Integrated Teaching on problem-solving ability among Class VIII students in the Science chapter *Exploring Forces*. The study compared the problem-solving ability of students in the experimental and control groups before and after the implementation of the instructional programme.

The findings revealed a statistically significant improvement in problem-solving ability among students in the experimental group. Their mean score increased from 69.53 in the pre-test to 73.67 in the post-test, showing a mean gain of 4.13 points. The control group also showed a statistically significant improvement, with its mean score increasing from 69.47 to 69.90, indicating a mean gain of 0.43 points.

The comparison of pre-test scores revealed no statistically significant difference between the experimental and control groups, indicating that both groups had comparable initial levels of problem-solving ability. Although the post-test comparison did not reveal a statistically significant difference between the groups, the experimental group obtained a higher mean score than the control group.

A further comparison of individual gain scores revealed a statistically significant difference between the experimental and control groups ($t = 10.184$, $p < 0.001$). The experimental group recorded a mean gain of 4.13, whereas the control group recorded a mean gain of 0.43. The difference of 3.70 points in mean improvement was statistically significant, indicating that students who received STEM-Based Integrated Teaching demonstrated significantly greater improvement in problem-solving ability than students who received conventional instruction.

These findings provide evidence in support of the effectiveness of STEM-Based Integrated Teaching in improving problem-solving ability among the selected Class VIII students. The integration of Science, Technology, Engineering and Mathematics through practical activities, investigations, experimentation, designing and application-based tasks may have provided meaningful opportunities for students to develop and apply problem-solving skills.

The study highlights the importance of adopting interdisciplinary and activity-oriented approaches in science education. Teachers should provide opportunities for students to identify problems, analyse situations, plan solutions, implement ideas and evaluate outcomes through meaningful learning experiences.

Finally, the gain-score analysis demonstrates that STEM-Based Integrated Teaching was significantly more effective than conventional teaching in improving problem-solving ability among the students included in the study. The findings emphasise the potential of integrating STEM-based activities into school Science instruction to promote problem-solving ability and the practical application of scientific knowledge.

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