SCIENCE EDUCATION

Effectiveness of Flipped Classroom Strategy on Conceptual Understanding of the Chapter 'Tissues' in Science among Secondary School Students

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Abstract

The chapter 'Tissues' helps students understand living organisms in an organised manner by explaining how groups of specialised cells work together to perform specific functions. Learning this chapter involves understanding the characteristics of different plant and animal tissues and the relationship between their structures and functions. Although students may remember the names of different tissues, they may experience difficulties in comparing tissue types, interpreting diagrams and explaining structure–function relationships. In this context, the present study investigated the effectiveness of the Flipped Classroom Strategy in improving students' conceptual understanding of the chapter Tissues in Science among Class IX secondary school students.

The study adopted a quasi-experimental pre-test–post-test non-equivalent control group design. A sample of 60 students was selected from one secondary school through intact classroom selection, comprising 30 students each in the experimental and control groups. The experimental group was taught using the Flipped Classroom Strategy, while the control group received conventional instruction. The intervention was conducted over six weeks, consisting of 12 instructional sessions. A researcher-developed Conceptual Understanding Test was used to collect data. 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 conceptual understanding of the experimental group ($t = 10.279$, $p < 0.001$), whereas the control group showed no statistically significant improvement ($t = 1.361$, $p = 0.184$). The comparison of pre-test scores showed no significant difference between the two groups ($t = 0.025$, $p = 0.980$). However, the post-test comparison revealed a statistically significant difference ($t = 2.687$, $p = 0.0094$), with the experimental group obtaining a higher mean score than the control group. The study concludes that the Flipped Classroom Strategy was more effective than conventional teaching in improving conceptual understanding of the chapter Tissues among the selected Class IX students.

Keywords: flipped classroom strategy; conceptual understanding; science education; tissues; secondary school students

1 Introduction

Science education becomes meaningful when students move beyond memorising facts and definitions towards developing a deeper understanding of scientific concepts and their relationships. In biological science, understanding how cells are organised into tissues is an important foundation for learning about the structure and functioning of living organisms. The chapter 'Tissues' introduces students to the organisation of specialised cells into groups that perform specific functions. It helps

students understand how different types of tissues contribute to the growth, support, protection, transportation and movement of living organisms.

The chapter 'Tissues' includes various concepts related to plant and animal tissues. Students learn about meristematic and permanent tissues in plants, along with different types of animal tissues. They are expected to identify the characteristics of each tissue, understand its location and explain its specific functions. For instance, understanding the transportation functions of xylem and phloem requires students to relate their structures to the movement of water, minerals and food materials in plants. Similarly, understanding muscular tissue becomes easier when students connect its structural features with the function of movement.

However, students may sometimes perceive these concepts as a collection of unfamiliar terms, classifications and definitions. They may memorise the functions of different tissues without fully understanding how their structures are related to their functions. Some students may also experience difficulties in identifying tissues from diagrams, distinguishing between different tissue types and applying their knowledge to unfamiliar situations. These challenges highlight the need for instructional approaches that provide opportunities for repeated learning, discussion, conceptual clarification and application.

In this context, the Flipped Classroom Strategy offers an alternative approach to organising the teaching-learning process. It provides students with opportunities to become familiar with the lesson content before classroom instruction and use classroom time for interactive activities, discussion, problem-solving and teacher-guided learning. The present study therefore examines the effectiveness of the Flipped Classroom Strategy in developing conceptual understanding of the chapter Tissues in Science among secondary school students.

1.1 The Flipped Classroom Strategy

The Flipped Classroom Strategy is an innovative instructional approach that reverses the traditional sequence of classroom teaching and individual learning. In this approach, students are introduced to the basic concepts of a lesson before attending the classroom through resources such as recorded video lectures, reading materials, diagrams, presentations or teacher-prepared learning sheets. Classroom time is subsequently utilised for discussion, clarification of doubts, collaborative activities, problem-solving and application of concepts.

The strategy provides students with opportunities to learn at their own pace by reviewing the pre-class learning materials whenever necessary. During classroom sessions, the teacher facilitates learning by addressing students' difficulties, explaining complex concepts and organising meaningful learning activities. Thus, the teacher's role is not reduced; rather, it becomes more focused on guiding, supporting and facilitating students' understanding.

In the context of science teaching, the Flipped Classroom Strategy can be implemented through pre-class videos, illustrated reading materials and concept-based worksheets. For the chapter *Tissues*, students may study the basic classification of plant and animal tissues before attending the classroom. Classroom activities can then include identifying tissues from diagrams, comparing their structural characteristics, matching tissues with their functions and discussing their importance in living organisms.

Therefore, the Flipped Classroom Strategy provides opportunities for students to engage actively with scientific concepts and utilise classroom time for deeper understanding and meaningful learning.

1.2 Conceptual understanding in the present study

Conceptual understanding refers to the ability of students to comprehend scientific ideas, recognise relationships among concepts, explain information meaningfully and apply their knowledge in different situations. It involves more than memorising definitions, classifications and factual information. Students with conceptual understanding can explain scientific concepts in their own words, distinguish between related ideas, interpret diagrams and establish relationships between structures and their functions.

For the purposes of this study, conceptual understanding refers to the ability of Class IX students to understand and explain the concepts included in the Science chapter Tissues. It includes identifying different types of plant and animal tissues, explaining their characteristics and functions, distinguishing between various tissue types, interpreting relevant diagrams and relating tissue structures to their specific functions.

The conceptual understanding of students will be assessed through a researcher-developed achievement test based on the prescribed content of the chapter. The test will include questions assessing factual knowledge, understanding, identification, comparison, diagram interpretation and application of scientific concepts. Thus, the study will examine students' ability to understand and apply the concepts of the selected chapter rather than merely recall textbook information.

1.3 Why a different classroom sequence may help

Students differ in their learning pace, prior knowledge and ability to understand new concepts. In a traditional classroom, the teacher generally introduces and explains the lesson during the instructional period. However, some students may require additional time to understand the concepts, while others may be ready to engage in higher-order learning activities.

The Flipped Classroom Strategy provides an opportunity to address these differences by introducing learning materials before classroom instruction. Students can watch recorded explanations, revisit difficult sections, read learning materials and note their doubts at their own pace. This preliminary preparation helps students become familiar with the concepts before participating in classroom activities.

The effectiveness of this strategy, however, depends on the quality of classroom instruction following the pre-class preparation. Simply providing videos or reading materials before class may not be sufficient to improve conceptual understanding. Classroom time should be utilised effectively through activities such as comparing different types of tissues, identifying tissue structures from diagrams, matching tissues with their functions, answering application-based questions and participating in guided discussions.

For example, students who have studied the basic characteristics of xylem and phloem before class can participate in activities that compare their structures and functions. Similarly, they can examine diagrams of muscular, nervous, epithelial and connective tissues and explain their distinctive features. Such activities provide opportunities for students to clarify misconceptions, connect related concepts and apply their knowledge with the guidance of the teacher.

Thus, the Flipped Classroom Strategy may create a more interactive and learner-centred environment by combining individual preparation with teacher-guided classroom activities. It provides opportunities for deeper engagement with scientific concepts and may contribute to the development of conceptual understanding.

1.4 Statement of the problem

The chapter 'Tissues' is an important component of biological Science at the secondary school level. It introduces students to the classification, characteristics, structure and functions of different types of plant and animal tissues. However, students may experience difficulties in understanding the relationships between tissue structures and their functions. They may memorise the names and classifications of tissues without developing a clear understanding of their organisation, characteristics and significance in living organisms.

Conventional classroom instruction may not always provide sufficient opportunities for students to revisit concepts, clarify individual doubts, interpret diagrams and apply scientific knowledge. Therefore, there is a need to explore alternative instructional approaches that promote active participation and meaningful learning.

The Flipped Classroom Strategy provides opportunities for students to become familiar with lesson content before classroom instruction and utilise classroom time for discussion, clarification, collaborative activities and application of concepts. In this context, the present study proposes to examine the effectiveness of the Flipped Classroom Strategy in improving the conceptual understanding of the chapter *Tissues* in Science among secondary school students.

2 Need and significance of the study

The chapter 'Tissues' is an important component of biological Science at the secondary school level because it introduces students to the organisation, characteristics and functions of different types of plant and animal tissues. Understanding this chapter requires students not only to remember the names and classifications of tissues but also to identify their structural features, explain their functions and establish relationships between their structures and functions. Students are expected to interpret diagrams, distinguish between different tissue types and apply their knowledge to scientific situations.

However, students may experience difficulties in understanding the interrelationships among the various concepts presented in the chapter. They may memorise definitions and classifications without developing a deeper conceptual understanding. This highlights the need for instructional approaches that provide opportunities for individual preparation, classroom interaction, discussion and application of scientific knowledge.

The Flipped Classroom Strategy offers an alternative approach by introducing students to basic learning content before classroom instruction and utilising classroom time for guided activities, clarification of doubts, discussion and problem-solving. This approach may enable students to prepare at their own pace and participate more meaningfully in classroom learning. The present study is therefore significant in examining whether the implementation of the Flipped Classroom Strategy can improve students' conceptual understanding of the chapter *Tissues*.

The significance of the study is discussed under the following headings.

2.1 Value for students

The Flipped Classroom Strategy provides students with opportunities to become familiar with scientific concepts before attending classroom sessions. They can revisit video explanations, diagrams, reading materials and worksheets at their own pace. This may help them identify difficult concepts and prepare specific questions for classroom discussion.

During classroom sessions, students can participate in comparison activities, diagram interpretation, concept-based exercises and teacher-guided discussions. These activities may help them distinguish between different types of tissues, understand their functions and develop the ability to explain scientific concepts in their own words. Thus, the strategy may contribute to deeper conceptual understanding and meaningful learning.

2.2 Value for science teachers

The study may provide Science teachers with an alternative instructional approach for organising classroom teaching. The Flipped Classroom Strategy enables teachers to identify students' prior understanding through pre-class activities and plan classroom instruction according to their learning difficulties.

Teachers can utilise classroom time more effectively by focusing on complex concepts, explaining the differences between simple and complex permanent tissues, discussing the relationship between tissue structure and function and guiding students in interpreting diagrams. The strategy may also encourage teachers to prepare appropriate digital and non-digital learning resources to support independent learning.

2.3 Value for the school

The study may help schools explore innovative approaches to improving the quality of science teaching and learning. The implementation of the Flipped Classroom Strategy can make effective use of existing educational resources, including digital devices, recorded lessons, printed notes, diagrams and worksheets.

Importantly, the strategy need not depend entirely on individual access to smartphones or continuous internet connectivity. Schools can provide printed learning materials, offline videos and shared digital resources to ensure that all students have reasonable opportunities to participate in pre-class preparation. Thus, the study may encourage the effective and inclusive use of available educational resources.

2.4 Value for teacher education

The study may be useful to teacher educators and prospective teachers in understanding the importance of innovative instructional approaches. It highlights the need for systematic lesson planning, preparation of learning resources, effective classroom interaction and continuous assessment of students' understanding.

Teacher education institutions can use the findings to encourage prospective teachers to develop skills in designing pre-class learning activities and organising meaningful classroom experiences. It may also help them understand that the successful implementation of technology-supported teaching depends not merely on the use of digital resources but on their appropriate integration with instructional objectives.

2.5 Value for assessment

The study highlights the importance of assessing conceptual understanding rather than depending entirely on the recall of factual information. Assessment of the chapter *Tissues* should include questions that require students to identify, compare, interpret, explain and apply scientific concepts.

For example, students may be presented with diagrams of different tissues and asked to identify their structural characteristics, distinguish between them or explain how their structures are related to their functions. Such assessment activities may provide a better understanding of students' conceptual development and help teachers identify areas requiring further clarification.

2.6 Value for educational research

The present study may contribute to educational research by providing context-specific evidence regarding the effectiveness of the Flipped Classroom Strategy in developing conceptual understanding among Class IX students studying under the Karnataka State Board curriculum.

The findings may provide a foundation for further investigations involving different Science topics, educational levels, school settings and student groups. They may also encourage researchers to examine the effectiveness of technology-supported and learner-centred instructional approaches in improving the quality of science education.

Overall, the study is significant because it explores an alternative approach to organising Science instruction that combines individual preparation with interactive classroom learning. It may provide useful insights for students, teachers, schools, teacher educators and educational researchers regarding the role of the Flipped Classroom Strategy in promoting conceptual understanding of scientific concepts.

3 Theoretical framework

The Flipped Classroom Strategy is best understood as an instructional approach that reorganises the teaching-learning process rather than as a learning theory that guarantees specific learning outcomes. Its effectiveness depends on the quality of pre-class learning materials, students' preparation and the nature of learning activities conducted during classroom instruction. The present study is supported by four important learning perspectives: Constructivist Learning Theory, Active Learning, Self-Regulated Learning and the role of Feedback in learning. These perspectives provide a theoretical foundation for understanding how the Flipped Classroom Strategy may contribute to the development of conceptual understanding among secondary school students.

3.1 Learning through connecting ideas

Constructivist Learning Theory emphasises that learners construct new knowledge by connecting it with their existing knowledge and experiences. Students do not simply receive information; they actively interpret and organise new ideas to develop meaningful understanding. While learning the chapter *Tissues*, students may already have some familiarity with plant parts such as roots, stems and leaves, and animal structures such as muscles and nerves. The teacher can use these familiar examples to introduce the concept of tissues and explain why specialised groups of cells perform particular functions.

In the Flipped Classroom Strategy, pre-class learning materials provide students with an initial introduction to the topic. Classroom discussions, questioning and guided activities then help students

connect new scientific concepts with their prior knowledge. This process may support a deeper understanding of the structure and functions of different plant and animal tissues.

3.2 Learning by actively engaging with content

Active Learning emphasises the importance of students' active participation in the learning process. Conceptual understanding is strengthened when students engage with information through activities such as questioning, discussion, comparison, interpretation and problem-solving.

In the present study, students will not merely listen to explanations of tissues such as xylem, phloem and epithelial tissue. Instead, they will participate in activities involving the identification of tissue types, interpretation of diagrams, comparison of structural features, matching tissues with their functions and explaining their observations. These activities will provide opportunities for students to apply scientific concepts and demonstrate their understanding. They will also enable the teacher to identify misconceptions and provide appropriate guidance.

3.3 Taking responsibility for preparation

Self-Regulated Learning refers to the process through which learners plan, monitor and evaluate their own learning. It encourages students to take responsibility for their learning by setting goals, managing learning activities and identifying areas that require further clarification.

The Flipped Classroom Strategy provides opportunities for students to develop these learning practices through pre-class preparation. In the present study, students will be encouraged to review the learning materials, attempt guiding questions and identify concepts that they find difficult to understand. This preparation will help them participate more meaningfully in classroom activities.

However, students may differ in their preparation habits, learning pace and access to digital resources. Therefore, the teacher will monitor their preparation and provide suitable alternatives, such as printed notes and worksheets, to ensure that all students have opportunities to participate in the learning process.

3.4 The role of feedback in learning

Feedback plays an important role in identifying learning difficulties, correcting misconceptions and strengthening conceptual understanding. Effective feedback helps students understand not only whether their responses are correct but also the reasons behind the correctness or incorrectness of their answers.

For example, if a student confuses the functions of xylem and phloem, the teacher can guide the student to examine the materials transported by each tissue and understand the differences between their functions. Similarly, misconceptions related to the structure and functions of plant and animal tissues can be addressed through questioning, discussion and clarification.

In the present study, oral questioning, short quizzes, classroom discussions and exit responses will provide opportunities for the teacher to offer timely feedback. Such feedback will help students review their understanding and make necessary corrections during the learning process.

3.5 Conceptual framework

The conceptual framework of the present study illustrates the relationship between the independent variable; the learning experiences provided through the intervention and the dependent variable. The

Flipped Classroom Strategy will be implemented through pre-class learning resources and planned classroom activities. These activities are expected to provide opportunities for students to develop a better understanding of the concepts related to plant and animal tissues. The components are summarised in Table 1.

Table 1. Conceptual framework of the study.

Part of the study	Description
Independent Variable	Flipped Classroom Strategy: Pre-class learning resources, guiding questions and planned classroom activities.
Learning Experiences	Pre-class preparation, questioning, peer discussion, diagram interpretation, comparison, explanation, practice activities and teacher feedback.
Dependent Variable	Conceptual Understanding of the chapter *Tissues* among secondary school students, assessed through a researcher-developed Conceptual Understanding Test.

The present study will examine whether the learning experiences provided through the Flipped Classroom Strategy led to a measurable improvement in students' conceptual understanding of the chapter *Tissues*. The relationship between the instructional strategy and the learning outcome will be examined through the collection and analysis of empirical data rather than assumed in advance.

4 Literature review

A review of related literature is an essential part of educational research. It provides an understanding of the research already conducted in a particular area, identifies important findings and highlights gaps that require further investigation. The present study focuses on the effectiveness of the Flipped Classroom Strategy on the conceptual understanding of the chapter *Tissues* in Science among secondary school students. The review therefore considers studies related to flipped classroom instruction, science and biology education, and its influence on students' learning outcomes.

4.1 Studies related to the Flipped Classroom Strategy

Van Alten et al. (2019) conducted a meta-analysis titled *Effects of Flipping the Classroom on Learning Outcomes and Satisfaction*. The study examined 114 research studies comparing flipped classroom instruction with traditional teaching. The findings indicated a small positive effect of flipped classroom instruction on students' learning outcomes. The researchers also observed that learning outcomes were better when classroom interaction time was maintained and quizzes were included as part of the instructional design. The study highlights the importance of purposeful classroom activities and regular assessment in implementing the flipped classroom approach.

Wright and Park (2022) conducted a systematic review titled *The Effects of Flipped Classrooms on K–16 Students' Science and Math Achievement*. The researchers analysed 30 empirical studies related to flipped classroom instruction in science and mathematics education. The findings indicated an overall positive influence of flipped classroom instruction on students' learning. However, the review also identified differences in the design and implementation of flipped classroom interventions. The authors emphasised the need for appropriate theoretical frameworks to guide the planning and evaluation of flipped classroom instruction.

Turan (2023) conducted a systematic review and meta-analysis titled *Evaluating Whether Flipped Classrooms Improve Student Learning in Science Education*. The study reviewed 64 research studies, of which 18 were included in the meta-analysis. The findings provided evidence regarding the application of flipped classroom instruction in science education. The review also indicated that many studies were conducted at the university level, with chemistry receiving considerable attention. The study highlights the need for further research on flipped classroom instruction at the school level and across different areas of science education.

4.2 Studies related to Flipped Classroom in secondary education

Li et al. (2025) published a meta-analysis titled *Effectiveness of Flipped Classrooms for K–12 Students: Evidence from a Three-Level Meta-Analysis*. The study synthesised evidence from 129 studies involving 12,727 students. The findings revealed a significant positive effect of flipped classroom instruction on the overall learning performance of school students. Positive effects were also identified in cognitive and affective learning domains. The researchers further observed that educational context and research methodology influenced the outcomes. The study provides substantial evidence supporting the investigation of flipped classroom instruction in secondary education.

4.3 Studies related to Flipped Classroom in biology education

Olana et al. (2025) conducted a study titled *The Impact of Flipped Classroom Strategy on Secondary School Students' Achievement in Biology*. The study employed a quasi-experimental design involving 105 secondary school students from two schools in Nekemte, Ethiopia. The experimental group consisted of 55 students, while the comparison group included 50 students. The intervention was conducted over 12 weeks, and a Biology Achievement Test was used to assess students' performance. The findings revealed that students taught through the flipped classroom strategy obtained significantly higher achievement scores than those taught through traditional instruction. The study demonstrates the potential of flipped classroom instruction in improving learning outcomes in secondary school biology.

Olana et al. (2026) conducted a study titled *Secondary School Students' Perceptions of the Flipped Classroom Approach in Biology Learning*. The study adopted a mixed-methods research design involving 105 students in the survey phase and 30 students in follow-up interviews. The findings indicated that students generally viewed the flipped classroom approach positively. Students appreciated the opportunity to learn at their own pace, revisit instructional videos and participate actively in classroom activities. The study also identified challenges such as technical difficulties and limited teacher interaction during pre-class learning. The researchers emphasised the importance of well-designed learning materials, structured classroom activities and adequate teacher support.

4.4 Summary of the review of related literature

The review of the above studies reveals that the Flipped Classroom Strategy has received considerable attention as a student-centred instructional approach. Research findings generally indicate that it can support students' learning outcomes when pre-class preparation is effectively combined with meaningful classroom activities.

The studies reviewed highlight the importance of active participation, peer interaction, formative assessment, teacher guidance and opportunities for independent preparation. Research conducted in science and biology education also suggests that the strategy has potential for improving students' learning outcomes. At the same time, the findings indicate that its effectiveness depends on

appropriate instructional planning, access to learning resources and support for students with different learning needs.

4.5 Research gap

Although several studies have examined the effectiveness of the Flipped Classroom Strategy in science and biology education, certain areas require further investigation. A considerable proportion of the reviewed research has focused on general academic achievement, overall learning performance and student perceptions. Comparatively, greater attention is needed to the development of specific conceptual understanding in individual science topics at the secondary school level.

In particular, the chapter *Tissues* involves understanding the characteristics, structures and functions of different types of plant and animal tissues. Students need to identify tissue types, interpret diagrams, distinguish between similar tissues and establish relationships between their structures and functions. These learning requirements make the chapter suitable for an instructional approach that combines pre-class preparation with classroom-based discussion, comparison and application activities.

Therefore, the present study proposes to investigate the effectiveness of the Flipped Classroom Strategy on the conceptual understanding of the chapter Tissues among Class IX secondary school students. It seeks to contribute context-specific evidence by focusing in improving students' conceptual understanding as the single dependent variable rather than examining only general academic achievement.

5 Objectives of the study

The present study aims with the following objectives:

To assess the pre-test level of conceptual understanding of the chapter *Tissues* among Class IX secondary school students in the experimental and control groups.

To develop and implement a Flipped Classroom Strategy for teaching the chapter *Tissues* in Science to Class IX students.

To assess the post-test level of conceptual understanding of the chapter *Tissues* among students in the experimental and control groups.

To determine the difference between the pre-test and post-test scores of students in the experimental group.

To determine the difference between the pre-test and post-test scores of students in the control group.

To compare the conceptual understanding of students in the experimental and control groups following the instructional intervention.

To examine the effectiveness of the Flipped Classroom Strategy in developing conceptual understanding of the chapter *Tissues* among Class IX secondary school students.

6 Hypotheses of the study

The following null hypotheses are formulated for this study:

$H_0$1: There is no significant difference between the pre-test and post-test scores of conceptual understandings of the chapter Tissues among students in the experimental group.

$H_0$2: There is no significant difference between the pre-test and post-test scores of conceptual understandings of the chapter Tissues among students in the control group.

$H_0$3: There is no significant difference between the pre-test scores of conceptual understandings of the chapter Tissues among students in the experimental and control groups.

$H_0$4: There is no significant difference between the post-test scores of conceptual understandings of the chapter Tissues among students in the experimental and control groups.

7 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 the Flipped Classroom Strategy in improving students' conceptual understanding of the chapter Tissues in Science among Class IX secondary school students. The methodology includes the research design, population, sample, sampling technique, variables, research tool, intervention procedure 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 the Flipped Classroom Strategy by comparing the conceptual understanding of students in the experimental and control groups.

The experimental group will be taught the chapter *Tissues* through the Flipped Classroom Strategy, whereas the control group will receive instruction through the conventional teaching method. Both groups will be administered a pre-test before the intervention and a post-test after the completion of the instructional programme.

7.2 Population of the study

The population of the present study will consist of Class IX 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** to select the participants. The sample of the present study will consist of 60 Class IX students selected from one secondary school following the Karnataka State Board curriculum. Two existing Class IX classroom groups from one secondary school will be selected for the study. One intact classroom will be designated as the experimental group, consisting of 30 students, and the other intact classroom will be designated as the control group, consisting of 30 students.

Individual students will not be randomly assigned to the groups, as 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: Flipped Classroom Strategy.

Dependent Variable: Conceptual Understanding of the chapter Tissues in Science.

7.5 Research tool

The researcher will develop a **Conceptual Understanding Test** based on the prescribed Class IX Science chapter *Tissues* of the Karnataka State Board curriculum.

The test will be designed to assess students' understanding of important concepts related to plant and animal tissues. It will include questions that assess the students' ability to:

Identify different types of plant and animal tissues.

Explain the characteristics and functions of various tissues.

Distinguish between different types of tissues.

Interpret and identify tissues from diagrams.

Relate the structure of tissues to their functions.

Apply conceptual knowledge to relevant questions.

The test will be subjected to content validation by the investigator. A pilot study will be conducted to examine the clarity, suitability and reliability of the test before its final administration.

7.6 Development and implementation of the Flipped Classroom Instructional Programme

The researcher will develop an instructional programme based on the Flipped Classroom Strategy for teaching the chapter *Tissues* in Science to Class IX students. The intervention will be implemented over a period of six weeks, with two instructional sessions per week, resulting in a total of 12 sessions.

The programme will be organised into two major stages:

7.6.1 Pre-class learning activities

Before each classroom session, students in the experimental group will be provided with suitable learning resources to develop an initial understanding of the concepts. These resources may include:

Short instructional videos.

Teacher-prepared explanations.

Digital or printed notes.

Diagrams and illustrations of different types of tissues.

Guiding questions and short preparation tasks.

Students will be encouraged to review the materials before attending the classroom session and identify concepts that require further clarification. Printed learning materials will also be provided to students who do not have access to digital resources.

7.6.2 *In-class learning activities*

During classroom sessions, students will participate in activities designed to strengthen their conceptual understanding. These activities will include:

Discussion and clarification of difficult concepts.

Identification and classification of plant and animal tissues.

Interpretation of tissue diagrams.

Comparison of different types of tissues.

Matching tissues with their respective functions.

Group activities and question-answer sessions.

Practice exercises and teacher feedback.

7.7 Duration of the intervention

The instructional intervention will be conducted for six weeks. Two sessions will be organised each week, resulting in a total of 12 instructional sessions.

The experimental group will receive instruction through the Flipped Classroom Strategy for 12 sessions, while the control group will receive conventional instruction covering the same chapter and instructional content.

7.8 Procedure of 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 IX students for the study.

Formation of Groups: The selected students will be organised into experimental and control groups using the available classroom arrangements.

Administration of Pre-test: A pre-test will be administered to both groups to assess their initial conceptual understanding of the chapter *Tissues*.

Implementation of the Intervention: The experimental group will be taught through the Flipped Classroom Strategy, while the control group will receive conventional instruction.

Administration of Post-test: After completing the instructional programme, the same test or an equivalent form of the test will be administered to both groups.

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.

7.9 Statistical techniques

The collected data will be analysed using appropriate 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 understand the variability in students' conceptual understanding 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 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. Students will be informed about the learning activities, and their participation will be carried out in accordance with appropriate ethical guidelines. Confidentiality of the collected data will be maintained. The instructional activities will be planned to ensure that students in both groups receive appropriate learning opportunities.

8 Implementation of the Flipped Classroom Strategy

The Flipped Classroom Strategy will be implemented to teach the chapter *Tissues* in Science to Class IX students. The instructional programme will be conducted over a period of six weeks, with two sessions per week, resulting in a total of 12 sessions. The experimental group, consisting of 30 students, will receive instruction through the Flipped Classroom Strategy, while the control group, consisting of 30 students, will be taught through the conventional teaching method.

The implementation will involve two major phases: pre-class preparation and in-class learning activities. This arrangement will provide students with opportunities to acquire initial knowledge before classroom instruction and use classroom time for discussion, clarification, application and practice.

8.1 Pre-class preparation

Before each classroom session, students in the experimental group will be provided with appropriate learning materials related to the topic to be taught. These materials will include short instructional videos, teacher-prepared notes, diagrams, illustrations and guiding questions.

Students will be encouraged to study the materials independently and attempt the assigned questions before attending the classroom session. They will also be asked to identify concepts that they find difficult to understand. Printed notes and worksheets will be provided as alternatives to digital resources to ensure that all students can participate in the preparation activities.

8.2 In-class learning activities

During classroom sessions, the teacher will facilitate active learning through various individual and group activities. Instead of spending the entire period delivering explanations, the teacher will focus on clarifying difficult concepts, addressing students' questions and providing opportunities for the application of knowledge.

The following activities will be organised:

Discussion and Clarification: Students will discuss the concepts studied before class and the teacher will clarify their doubts.

Identification of Tissues: Students will identify different types of plant and animal tissues using diagrams and illustrations.

Diagram Interpretation: Students will observe and interpret diagrams of various tissues and identify their important features.

Comparison Activities: Students will compare different types of tissues based on their structure, characteristics and functions.

Matching Activities: Students will match different tissues with their respective locations and functions.

Group Learning: Students will participate in group discussions and collaborative learning activities related to the chapter.

Questioning and Practice: Students will answer conceptual questions and solve practice exercises.

Teacher Feedback: The teacher will provide immediate feedback, correct misconceptions and reinforce important scientific concepts.

8.3 Session-wise implementation plan

The Flipped Classroom Strategy 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	Content / Topic	Planned Learning Activities
1	1	Introduction to Tissues	Pre-class reading, introductory discussion and explanation of the concept of tissues.
1	2	Plant Tissues – Meristematic Tissue	Study of learning materials, identification of meristematic tissue and discussion of its characteristics and functions.
2	3	Permanent Tissues – Simple Permanent Tissue	Diagram interpretation and comparison of parenchyma, collenchyma and sclerenchyma.
2	4	Complex Permanent Tissue	Discussion and comparison of xylem and phloem based on their structure and functions.
3	5	Animal Tissues – Epithelial Tissue	Identification of epithelial tissue types and discussion of their locations and functions.
3	6	Connective Tissue	Classification and comparison of different connective tissues through diagrams and examples.
4	7	Muscular Tissue	Identification and comparison of striated, smooth and cardiac muscles.
4	8	Nervous Tissue	Interpretation of neuron diagrams and discussion of the structure and functions of nervous tissue.
5	9	Comparison of Plant Tissues	Classification, comparison and application-based activities related to plant tissues.
5	10	Comparison of Animal Tissues	Group discussion, diagram-based activities and comparison of different animal tissues.
6	11	Integrated Revision of Tissues	Conceptual questions, matching activities, diagram interpretation and clarification of misconceptions.

Week	Session	Content / Topic	Planned Learning Activities
6	12	Consolidation and Practice	Review of the chapter, application-based questions and final clarification of concepts.

8.4 Role of the teacher

The teacher will act as a facilitator and guide throughout the implementation of the Flipped Classroom Strategy. The teacher will prepare appropriate learning resources, provide pre-class instructions, monitor students' preparation and organise meaningful classroom activities. Special attention will be given to identifying misconceptions and providing timely feedback to strengthen students' conceptual understanding.

8.5 Role of students

Students will take an active role in the learning process by reviewing the materials provided before class, attempting guiding questions, participating in classroom discussions and completing assigned activities. They will be encouraged to ask questions, interpret diagrams, compare tissue structures and explain the relationship between the structure and function of different tissues.

8.6 Instruction to the control group

The control group, consisting of 30 students, will be taught the same chapter, *Tissues*, through the conventional teaching method. The teacher will explain the concepts using classroom instruction, textbooks, diagrams and relevant examples. The instructional content and overall duration will be comparable to those of the experimental group to facilitate a meaningful comparison of conceptual understanding.

8.7 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 conceptual understanding of the chapter *Tissues*. The post-test scores will be compared with the pre-test scores to examine changes in conceptual understanding and determine the effectiveness of the Flipped Classroom Strategy.

9 Analysis and interpretation

9.1 Hypothesis 1

There is no significant difference between the pre-test and post-test scores of conceptual understandings of the chapter Tissues 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	17.50	5.01	10.279	< 0.001	Significant
Post-test	30	20.77	3.80			

Table 3 presents the comparison of pre-test and post-test scores of the experimental group. The mean pre-test score was 17.50, with a standard deviation of 5.01, whereas the mean post-test score was

20.77, with a standard deviation of 3.80. The calculated paired-samples t-value was 10.279, which indicates statistical significance at the 0.001 level ($p < 0.001$).

The results indicate a significant improvement in students' conceptual understanding of the chapter Tissues after the implementation of the Flipped Classroom Strategy. Therefore, the null hypothesis is rejected. It can be concluded that the experimental group demonstrated significantly higher conceptual understanding in the post-test than in the pre-test. The scores are shown in Figure 1.

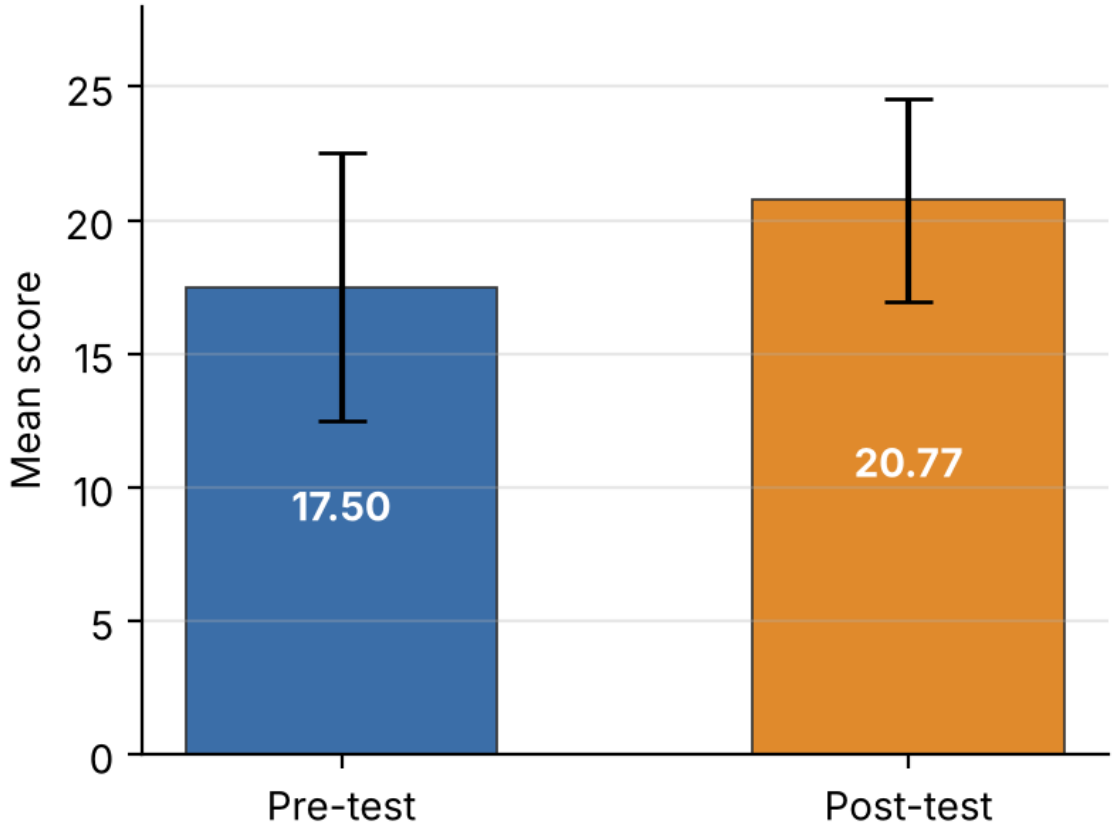


Figure 1. Mean pre-test and post-test scores of the experimental group (error bars, standard deviation).

9.2 Hypothesis 2

There is no significant difference between the pre-test and post-test scores of conceptual understandings of the chapter Tissues 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	17.47	5.17	1.361	0.184	Not Significant
Post-test	30	17.67	5.05			

Table 4 presents the comparison of pre-test and post-test scores of the control group. The mean pre-test score was 17.47, with a standard deviation of 5.17, whereas the mean post-test score was 17.67, with a standard deviation of 5.05. The calculated paired-samples t-value was 1.361, with a p-value of 0.184, which exceeds the 0.05 significance level.

The results show that there was no statistically significant difference between the pre-test and post-test scores of the control group. Although a slight increase in the mean score was observed, the improvement was not statistically significant. Therefore, the null hypothesis is not rejected. It can be concluded that conventional teaching did not produce a statistically significant improvement in the conceptual understanding of the chapter Tissues among the students in the control group during the study period. The scores are shown in Figure 2.

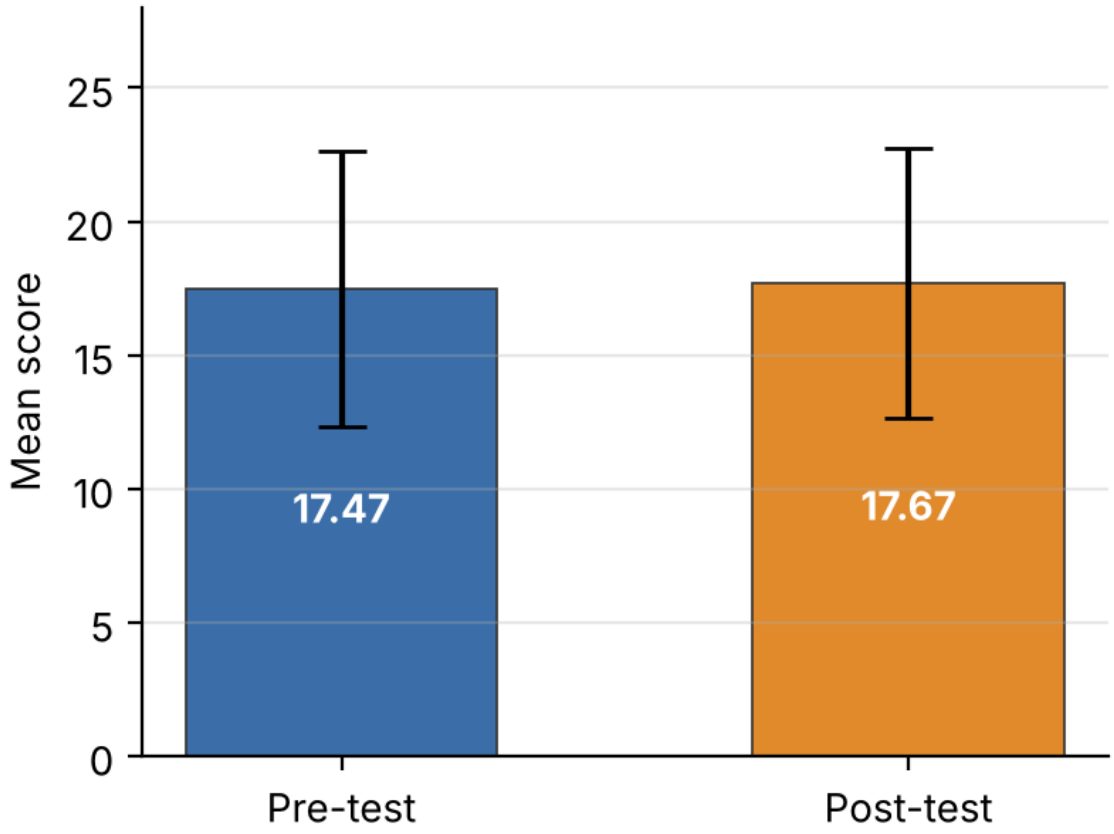


Figure 2. Mean pre-test and post-test scores of the control group (error bars, standard deviation).

9.3 Hypothesis 3

There is no significant difference between the pre-test scores of conceptual understanding of the chapter Tissues 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	17.50	5.01	0.025	0.980	Not Significant
Control	30	17.47	5.17			

Table 5 presents the comparison of the pre-test conceptual understanding scores of the chapter Tissues among students in the experimental and control groups. The experimental group obtained a mean score of 17.50 with a standard deviation of 5.01, whereas the control group obtained a mean score of 17.47 with a standard deviation of 5.17.

The calculated t-value was 0.025, with a p-value of 0.980, which exceeds the 0.05 significance level. Hence, the difference between the pre-test mean scores of the two groups is not statistically significant.

Therefore, the null hypothesis is not rejected. It can be concluded that the experimental and control groups had comparable initial levels of conceptual understanding of the chapter Tissues before the implementation of the instructional intervention. The scores are shown in Figure 3.

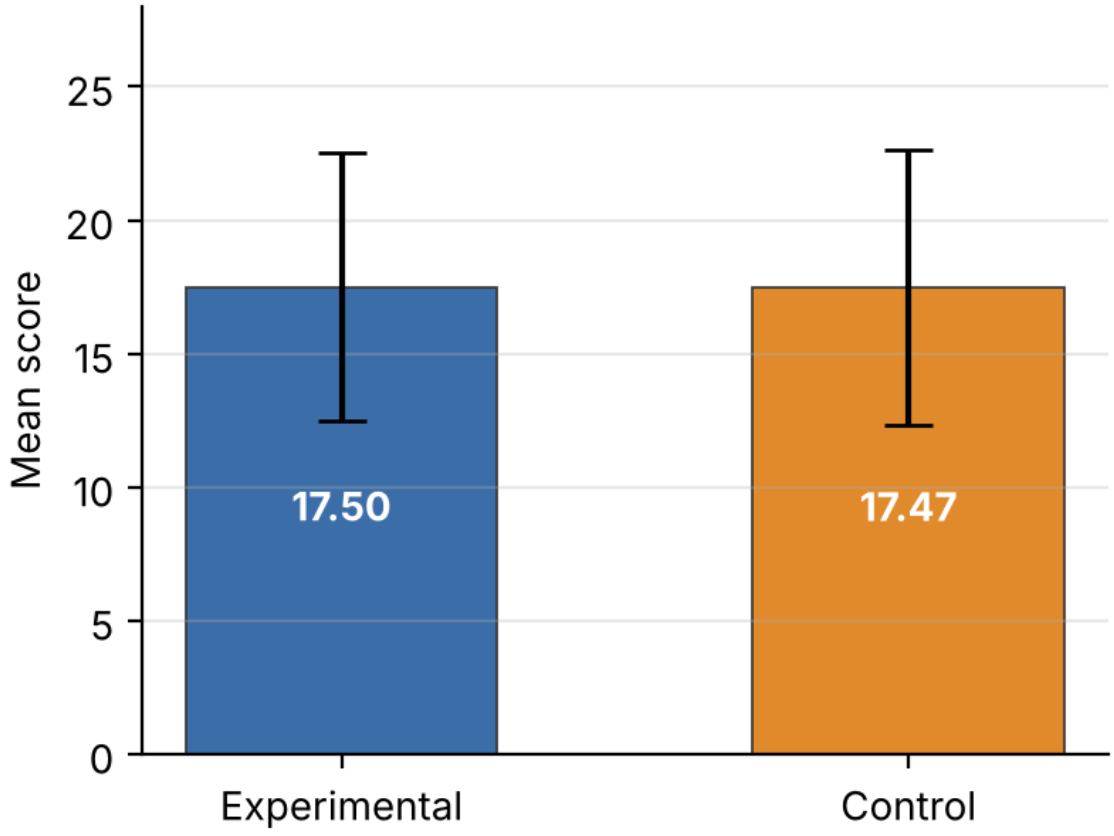


Figure 3. Mean pre-test scores of students in the experimental and control groups (error bars, standard deviation).

9.4 Hypothesis 4

There is no significant difference between the post-test scores of conceptual understanding of the chapter Tissues 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	20.77	3.80	2.687	0.0094	Significant
Control	30	17.67	5.05			

Table 6 presents the comparison of the post-test conceptual understanding scores of the chapter Tissues among students in the experimental and control groups. The experimental group obtained a mean score of 20.77 with a standard deviation of 3.80, whereas the control group obtained a mean score of 17.67 with a standard deviation of 5.05.

The calculated t-value was 2.687, with a p-value of 0.009, which is below the 0.05 significance level. Hence, the difference between the post-test mean scores of the two groups is statistically significant.

Therefore, the null hypothesis is rejected. It can be concluded that students in the experimental group demonstrated significantly higher conceptual understanding of the chapter Tissues than students in the control group after the instructional intervention. The findings indicate that the Flipped Classroom Strategy was more effective than conventional teaching in improving students' conceptual understanding in the present study. The scores are shown in Figure 4.

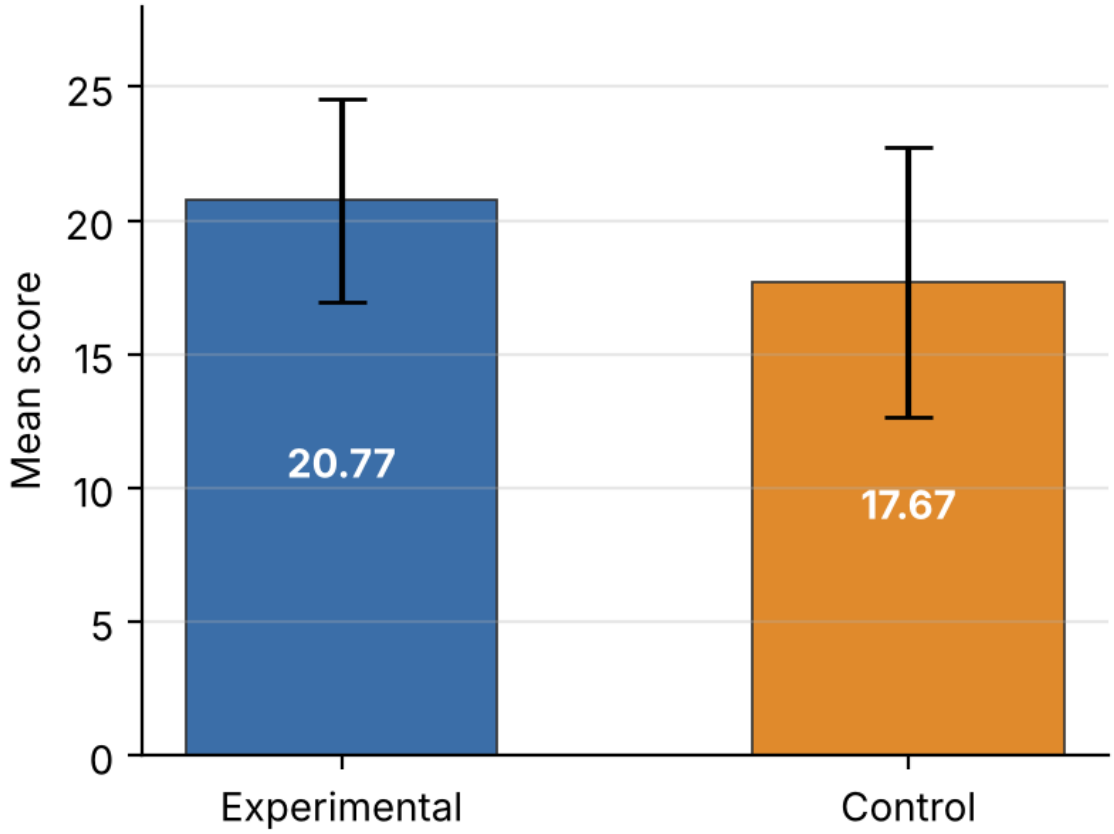


Figure 4. Mean post-test scores of students in the experimental and control groups (error bars, standard deviation).

10 Findings of the study

A statistically significant difference was found between the pre-test and post-test conceptual understanding scores of students in the experimental group. Students demonstrated higher conceptual understanding after receiving instruction through the Flipped Classroom Strategy.

There was no statistically significant difference found between the pre-test and post-test conceptual understanding scores of students in the control group.

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

A statistically significant difference was found between the post-test conceptual understanding scores of students in the experimental and control groups. Students in the experimental group obtained a higher mean score than students in the control group.

The experimental group demonstrated a greater improvement in conceptual understanding than the control group, as reflected in the difference between their pre-test and post-test mean scores.

11 Discussion of the findings

The present study investigated the effectiveness of the Flipped Classroom Strategy in improving students' conceptual understanding of the chapter Tissues in Science among Class IX secondary school students. The findings revealed that the Flipped Classroom Strategy contributed positively to students' conceptual understanding when compared with conventional teaching.

The experimental group demonstrated a statistically significant improvement in conceptual understanding from the pre-test to the post-test. The mean score increased from 17.50 to 20.77, indicating an improvement of 3.27 points. This improvement may be attributed to the opportunities provided by the Flipped Classroom Strategy for students to study learning materials before class, revisit scientific concepts and participate actively in classroom activities. The pre-class preparation enabled students to develop an initial understanding, while classroom discussions, diagram interpretation and comparison activities helped them clarify and strengthen their knowledge.

In contrast, the control group did not demonstrate a statistically significant improvement between the pre-test and post-test. The mean score increased slightly from 17.47 to 17.67, showing an improvement of only 0.20 points. This suggests that conventional teaching, as implemented during the study period, did not produce a statistically significant improvement in students' conceptual understanding.

The comparison of pre-test scores revealed no statistically significant difference between the experimental and control groups. The mean scores were 17.50 and 17.47, respectively. This indicates that both groups had comparable initial levels of conceptual understanding before the implementation of the instructional intervention. Therefore, the comparison of post-test performance provides a useful basis for examining the outcomes of the two instructional approaches.

The comparison of post-test scores revealed a statistically significant difference between the experimental and control groups. The experimental group obtained a higher mean score of 20.77 compared with 17.67 for the control group. This finding indicates that students who received instruction through the Flipped Classroom Strategy demonstrated better conceptual understanding than those who received conventional instruction.

The improvement observed in the experimental group may be explained through the learning perspectives discussed in the theoretical framework. From a constructivist perspective, students were able to connect new scientific concepts with their existing knowledge. Active learning activities provided opportunities to identify, compare and interpret different types of plant and animal tissues. Pre-class preparation also encouraged students to take greater responsibility for their learning, while teacher feedback helped clarify misconceptions related to tissue structure and function.

The findings are also consistent with the broader research evidence reviewed in the literature, which indicates that flipped classroom instruction can support students' learning outcomes when independent preparation is combined with meaningful classroom interaction and teacher guidance.

Overall, the findings suggest that the Flipped Classroom Strategy was more effective than the conventional teaching method in improving conceptual understanding of the chapter *Tissues* among the selected Class IX students. However, since the study was conducted using intact classrooms in a single school, the findings should be interpreted within the context of the sample and research design.

12 Educational implications

The findings of the present study have several important implications for science education, particularly in improving the conceptual understanding of secondary school students. The study indicates that the Flipped Classroom Strategy can provide meaningful learning opportunities when pre-class preparation is combined with active classroom participation. The following are the major educational implications:

Promotion of Student-Centred Learning: Science teachers should adopt student-centred instructional strategies that encourage active participation, independent preparation and meaningful interaction rather than depending entirely on traditional lecture-based teaching.

Improvement of Conceptual Understanding: Teachers should provide opportunities for students to identify, classify, compare and interpret scientific concepts. Activities related to plant and animal tissues can help students understand the relationship between tissue structure and function.

Effective Utilisation of Classroom Time: The Flipped Classroom Strategy enables teachers to utilise classroom time for discussion, clarification, problem-solving and application-based activities instead of spending the entire period explaining basic concepts.

Integration of ICT in Science Teaching: Teachers should make effective use of digital learning resources such as instructional videos, presentations, animations and digital diagrams to support pre-class learning and enhance the teaching-learning process.

Development of Independent Learning Habits: Pre-class preparation encourages students to take responsibility for their learning by reviewing materials, attempting questions and identifying concepts that require further clarification.

Encouragement of Collaborative Learning: Teachers should organise group discussions, peer learning, comparison activities and collaborative tasks to provide opportunities for students to share ideas and develop a deeper understanding of scientific concepts.

Identification and Correction of Misconceptions: Teachers should use questioning, short quizzes, diagram-based activities and timely feedback to identify students' misunderstandings and provide appropriate remedial support.

Inclusive Learning Opportunities: Schools and teachers should provide printed notes, worksheets and other offline learning materials for students who have limited access to digital devices or internet facilities. This will help ensure equal opportunities for participation.

Implications for Teacher Education: Teacher education institutions should provide training to prospective teachers in planning flipped classroom lessons, preparing digital learning resources, designing interactive activities and assessing conceptual understanding.

Curriculum and Instructional Planning: Curriculum developers and educational administrators should encourage the inclusion of flexible, activity-based and technology-supported instructional approaches in school science education.

Use of Innovative Assessment Strategies: Teachers should move beyond memory-based assessments and include questions that assess identification, comparison, explanation, diagram interpretation and application of scientific concepts.

Professional Development of Teachers: In-service teacher training programmes should familiarise teachers with innovative instructional strategies such as the Flipped Classroom Strategy and help them integrate these approaches effectively into classroom teaching.

Overall, the study highlights the importance of adopting innovative and learner-centred instructional strategies in science education. The Flipped Classroom Strategy can provide a supportive learning environment in which students prepare independently, participate actively in classroom activities and develop a better conceptual understanding of scientific concepts.

13 Suggestions for further research

The present study was limited to investigating the effectiveness of the Flipped Classroom Strategy in improving students' conceptual understanding of the chapter Tissues in Science among Class IX secondary school students. Based on the scope and limitations of the study, the following suggestions are made for further research:

Similar studies may be conducted with a larger sample involving students from different secondary schools to improve the generalisability of the findings.

Further studies may be undertaken among students studying in different classes, such as Classes VIII, IX and X, to examine the effectiveness of the Flipped Classroom Strategy at different educational levels.

The effectiveness of the Flipped Classroom Strategy may be investigated in other Science topics, such as the fundamental unit of life, force and motion, natural resources and other biology-related concepts.

Comparative studies may be conducted to examine the effectiveness of the Flipped Classroom Strategy with other innovative instructional strategies, such as the Jigsaw Method, Inquiry-Based Learning, Project-Based Learning and Blended Learning.

Further research may be conducted in different geographical areas, including rural and urban schools, to examine the applicability of the Flipped Classroom Strategy in varied educational contexts.

Studies may be undertaken to compare the effectiveness of digital video-based preparation with printed learning materials in implementing the Flipped Classroom Strategy.

Further investigations may examine the effectiveness of the Flipped Classroom Strategy among students with different levels of prior knowledge and learning abilities.

Longitudinal studies may be conducted to examine the retention of conceptual understanding over an extended period after the implementation of the Flipped Classroom Strategy.

Similar studies may be undertaken in different subject areas, such as Mathematics, Social Science and Languages, to explore the applicability of the Flipped Classroom Strategy across the school curriculum.

Further studies may investigate the effectiveness of different types of pre-class learning resources, including instructional videos, animations, interactive presentations and teacher-prepared worksheets, in supporting students' conceptual understanding.

Research may be conducted with a larger sample and a longer intervention period to examine whether the findings of the present study can be replicated in different school settings.

Further experimental studies may be undertaken using different research designs and appropriate statistical techniques to establish stronger evidence regarding the effectiveness of the Flipped Classroom Strategy.

Overall, further research in these areas may provide a broader understanding of the possibilities and limitations of the Flipped Classroom Strategy in school education. Such studies may also contribute to the development of effective, inclusive and student-centred instructional practices.

14 Conclusion

The present study investigated the effectiveness of the Flipped Classroom Strategy in improving students' conceptual understanding of the chapter Tissues in Science among Class IX secondary school students. The study was conducted using a quasi-experimental pre-test–post-test non-equivalent control group design involving 60 students from one secondary school. The sample consisted of 30 students in the experimental group and 30 students in the control group. The instructional intervention was implemented over six weeks, comprising 12 sessions.

The findings revealed a statistically significant improvement in the conceptual understanding of students in the experimental group after the implementation of the Flipped Classroom Strategy. In contrast, the control group did not demonstrate a statistically significant improvement after receiving conventional instruction. The comparison of pre-test scores indicated that both groups had comparable initial levels of conceptual understanding. However, the post-test results revealed a statistically significant difference between the two groups, with the experimental group obtaining a higher mean score than the control group.

The findings suggest that the Flipped Classroom Strategy provides meaningful opportunities for students to prepare independently, participate actively in classroom discussions, interpret scientific diagrams, compare different types of tissues and clarify their doubts through teacher guidance and feedback. It also enables teachers to utilise classroom time more effectively for interactive and application-based learning activities.

The study highlights the importance of moving beyond traditional teacher-centred instruction towards innovative and student-centred approaches in science education. The integration of pre-class learning resources with classroom-based activities can create opportunities for meaningful learning and better conceptual understanding.

In conclusion, the Flipped Classroom Strategy was found to be more effective than conventional teaching in improving the conceptual understanding of the chapter *Tissues* among the selected Class IX students. Although the findings are encouraging, they should be interpreted within the limitations of the sample and the quasi-experimental design. The study emphasises the importance of adopting

innovative instructional strategies to make science learning more meaningful, interactive and concept-oriented.

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