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Effectiveness of Gamification-Based Science Teaching on Academic Achievement Among Secondary School Students

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Abstract: Students' academic achievement in science depends not only on the content taught but also on their active participation in the learning process. Some scientific concepts involve unfamiliar terms, structures and processes that require meaningful understanding. Conventional teacher-centred instruction may not always provide sufficient opportunities for active participation and sustained engagement. Gamification-based teaching offers an innovative instructional approach by integrating selected game-design elements into regular classroom instruction to make learning more engaging, purposeful and interactive. The present study aimed to examine the effectiveness of gamification-based Science teaching on the academic achievement of secondary school students, with special reference to the Class IX Science chapter '*The Fundamental Unit of Life*'. The study adopted a quasi-experimental pre-test–post-test non-equivalent control group design. The sample consisted of 60 Class IX students from a selected secondary school, comprising 30 students in the experimental group and 30 students in the control group. The experimental group received gamification-based Science instruction through structured learning missions, points, badges, levels, quizzes, puzzles, team challenges and immediate feedback, whereas the control group received conventional instruction covering the same content. A researcher-developed Science Achievement Test was used to assess students' academic achievement before and after the intervention. 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 academic achievement of the experimental group ($t = 10.279$, $p < 0.001$), whereas the improvement in the control group was not statistically significant ($t = 1.361$, $p = 0.184$). The comparison of pre-test scores indicated no significant difference between the two groups ($t = 0.025$, $p = 0.980$). However, the post-test comparison revealed a statistically significant difference in favour of the experimental group ($t = 2.687$, $p = 0.0094$). The comparison of gain scores also indicated significantly greater improvement in the experimental group. These findings suggest that gamification-based Science teaching can serve as an effective supplementary instructional approach for improving academic achievement and making Science learning more interactive and meaningful among secondary school students.

Keywords: *Gamification-Based Teaching, Academic Achievement, Science Education, the Fundamental Unit of Life, Secondary School Students, Experimental Research.*

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I. INTRODUCTION

Education helps learners build the knowledge, skills, attitudes and values they need for personal development and responsible participation in society. At the secondary school stage, students encounter scientific ideas that explain the natural world, living organisms and the physical environment. Science education should therefore nurture curiosity, careful observation, reasoning and the ability to use scientific knowledge in everyday life.

Academic achievement in science refers to the extent to which students acquire and demonstrate the knowledge and understanding intended by the curriculum. Achievement is influenced by several factors, including prior knowledge, learning opportunities, classroom interaction, teaching methods, motivation, study habits and the quality of assessment. When students are given opportunities to participate, question, practice and receive feedback, they may develop a clearer understanding of scientific concepts.

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In the chapter 'The Fundamental Unit of Life', students learn that the cell is the basic structural and functional unit of living organisms. It includes concepts such as the discovery and structure of the cell, cell membrane, cell wall, nucleus, cytoplasm and cell organelles. Students are expected to distinguish between plant and animal cells, understand the functions of important organelles and relate cell structure to cellular activities. Some of these concepts are abstract and involve specialized vocabulary, making appropriate visualization, repetition and active learning important.

In many classrooms, Science lessons may rely substantially on explanation, textbook reading, note-taking and written exercises. These approaches remain useful, but they may not always provide sufficient variety or sustained participation for all students. Learners may memorize the names of organelles without fully understanding their functions or relationships. Teachers may therefore explore learner-centered approaches that make students active participants while maintaining the accuracy and depth of the prescribed content.

Gamification is one such approach. It involves the purposeful use of selected game-design elements in a non-game learning context. Elements such as goals, points, badges, levels, progress indicators, challenges, team missions, feedback and recognition can be integrated into ordinary lessons. The purpose is not merely to entertain students or turn the lesson into a game. Rather, gamification structures learning tasks so that students have clear goals, opportunities to practice, timely feedback and visible evidence of progress.

When used thoughtfully, gamification can support participation and provide repeated opportunities to retrieve and apply knowledge. For example, students learning about cell organelles may complete a "Cell Explorer Mission", match organelles with their functions, solve a labelled-cell puzzle, answer short quizzes and work in teams to complete a cell-model challenge. Points and badges can recognize effort, accuracy, improvement and collaboration rather than rewarding only the fastest students.

Research reviews indicate that gamification can have positive effects on learning outcomes, although effects vary according to the design, context and implementation of the intervention. Sailer and Homner (2020) reported positive effects across cognitive, motivational and behavioral learning outcomes in their meta-analysis. Such findings support further classroom-based investigation while also highlighting the need to evaluate a clearly defined intervention rather than assuming that every game element automatically improves learning.

In this context, the present study proposes to investigate whether systematic gamification-based teaching of 'The Fundamental Unit of Life' can improve the academic achievement of Class IX students when compared with conventional teaching of the same content.

➢ *Concept of Gamification-Based Teaching*

Gamification-based teaching refers to the systematic integration of selected game-design elements into teaching and learning activities that are not themselves complete games. Deterding, Dixon, Khaled and Nacke (2011) define gamification as the use of game-design elements in non-game contexts. In education, gamification is used to organise learning experiences through clearly defined goals, challenges, rewards, feedback and opportunities for active participation.

Gamification should be distinguished from game-based learning. In game-based learning, a complete game is used as the primary medium for teaching and learning. In gamification, the regular curriculum, subject content and instructional objectives remain central, while selected game elements are incorporated into classroom activities to enhance student engagement and learning experiences.

The major elements of gamification-based teaching proposed for the present study are as follows:

- Learning Missions or Quests: Students complete a sequence of curriculum-related tasks to achieve specific learning objectives.
- Points: Points are awarded for correct responses, task completion, improvement and meaningful participation.
- Badges: Badges recognise specific achievements, such as "Organelle Expert" and "Cell Structure Investigator".
- Levels: Different levels represent students' progress from basic identification to understanding, explanation and application of scientific concepts.
- Quizzes and Puzzles: These activities provide opportunities for retrieval practice, reinforcement and assessment of conceptual understanding.
- Team Challenges: Group-based activities encourage peer interaction, discussion and collaborative problem-solving.
- Immediate Feedback: Timely feedback helps students identify errors, correct misconceptions and improve their understanding.

Effective gamification requires proper alignment between game elements and instructional objectives. Points should reward meaningful learning activities rather than mere participation. Challenges should be interesting and appropriate to students' learning levels. Feedback should guide students towards correct understanding, while competition should remain positive and inclusive.

For the present investigation, gamification-based teaching is operationally defined as the planned and systematic teaching of the Class IX Science chapter "The Fundamental Unit of Life" through curriculum-based missions, quizzes, puzzles, points, badges, progress levels, team challenges and immediate feedback during the instructional intervention.

➢ *Concept of Academic Achievement*

Academic achievement refers to the extent to which students acquire and demonstrate the knowledge, understanding and competencies expected through planned

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educational experiences. It indicates the extent to which students have attained the intended learning objectives of a particular subject or instructional programme.

In Science, academic achievement includes the ability to recall scientific facts, understand concepts, explain relationships, interpret diagrams, identify scientific structures and apply acquired knowledge to familiar situations. It also reflects students' understanding of scientific principles and their ability to answer questions based on the prescribed curriculum.

In the chapter “The Fundamental Unit of Life”, academic achievement involves students' ability to identify different cell structures, explain the functions of cell organelles, distinguish between plant and animal cells, interpret cell diagrams and understand selected cellular processes.

For the present investigation, academic achievement is operationally defined as the score obtained by Class IX students in a researcher-developed achievement test based on the prescribed Science chapter “The Fundamental Unit of Life”. The test will be administered before and after the instructional intervention to measure any changes in students’ academic achievement.

- *Gamification and Science Learning*

Science learning involves the development of scientific knowledge, conceptual understanding, observation, reasoning and application of scientific principles. Gamification-based teaching can support these learning processes when game-design elements are meaningfully connected with instructional objectives and classroom activities.

Gamification provides opportunities for students to participate in quizzes, puzzles, missions, challenges and interactive tasks. Short quizzes encourage students to recall previously learned information, matching activities help them associate scientific structures with their functions, and visual puzzles support the interpretation of scientific diagrams. Similarly, progressive learning missions enable students to move from basic understanding towards higher levels of conceptual application.

In the Class IX Science chapter ‘The Fundamental Unit of Life’, students are expected to understand the structure and functions of cells and their components. Through gamification-based activities, students can identify cell organelles, match them with their functions, label cell diagrams and compare plant and animal cells. Activities such as "Cell Explorer Mission", "Organelle Matching Challenge" and "Cell Structure Puzzle" can make the learning process more interactive and purposeful.

Gamification also provides opportunities for repeated practice and immediate feedback. Students can identify their mistakes, revise scientific concepts and attempt learning tasks again. The teacher plays an important role in explaining scientific concepts, guiding classroom activities, correcting misconceptions and ensuring that all gamified activities are aligned with the prescribed curriculum.

Thus, gamification-based teaching can serve as a supportive instructional strategy for promoting active participation, reinforcing scientific concepts and providing meaningful learning experiences. The present study aims to examine its effectiveness in improving the academic achievement of secondary school students.

- *Statement of the Problem*

Science is an important school subject that helps students understand the natural world and develop scientific knowledge and reasoning abilities. However, students may experience difficulties in understanding and remembering scientific concepts involving unfamiliar terminology, abstract structures and complex processes.

The Class IX Science chapter “The Fundamental Unit of Life” introduces students to the basic structure and functions of cells and their components. Students are expected to understand cell organelles, their functions, the differences between plant and animal cells and selected cellular processes. Learning these concepts requires appropriate instructional strategies, repeated practice, visual representation and meaningful classroom participation.

Conventional teaching methods, including explanation, textbook reading and written exercises, are important components of classroom instruction. However, depending exclusively on these methods may not always provide sufficient opportunities for active engagement, interactive practice and immediate feedback for every student.

Gamification-based teaching offers an alternative instructional approach by incorporating learning missions, points, badges, levels, quizzes, puzzles, team challenges and feedback into regular classroom teaching. These elements may provide opportunities for students to participate actively, practise scientific concepts and monitor their learning progress. Nevertheless, the effectiveness of such an approach needs to be examined through systematic classroom-based research.

Therefore, the present study aims to investigate the effectiveness of gamification-based Science teaching on the academic achievement of secondary school students, with special reference to the Class IX Science chapter “The Fundamental Unit of Life”. The study is titled "Effectiveness of Gamification-Based Science Teaching on Academic Achievement among Secondary School Students."

II. NEED AND SIGNIFICANCE OF THE STUDY

Science education should focus on developing meaningful conceptual understanding rather than encouraging students to depend only on memorisation. The chapter “The Fundamental Unit of Life” includes several scientific terms, cell structures, functions and diagrams that require systematic explanation, visualisation and repeated

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practice. Therefore, appropriate instructional strategies are necessary to make the learning process meaningful, active and effective.

Gamification-based teaching offers opportunities to organise classroom learning through missions, points, badges, levels, quizzes, puzzles, team challenges and immediate feedback. These elements may encourage students to participate actively, practise scientific concepts and monitor their learning progress. The present study is significant because it examines the effectiveness of this instructional approach in improving the academic achievement of Class IX students in science.

- *Importance for Students*

Gamification-based teaching may make Science learning more interesting, active and participatory. Learning missions, quizzes and puzzles provide opportunities for students to practise scientific terminology, identify cell structures, understand the functions of organelles and interpret diagrams. Points, badges and progress indicators may help students recognise their learning progress and encourage continuous participation.

- *Importance for Teachers*

The study may provide Science teachers with a practical instructional model for integrating game-design elements into regular classroom teaching. It may help teachers organise textbook content into structured learning missions, formative quizzes, team challenges and revision activities. The findings may also encourage teachers to adopt innovative teaching strategies without compromising the prescribed curriculum and learning objectives.

- *Importance for Schools*

The study may help schools recognise the educational value of learner-centred and activity-oriented teaching approaches. The proposed intervention can be implemented using ordinary classroom materials such as charts, flashcards, worksheets, diagrams and quiz cards. Therefore, schools with limited digital facilities may also consider adopting gamification-based instructional activities.

- *Importance for Teacher Education*

The study may be useful for teacher education institutions in preparing prospective teachers to design and implement innovative instructional strategies. B.Ed. student-teachers may gain an understanding of how game-design elements can be integrated with subject content, learning objectives and classroom assessment. It may also encourage future teachers to select instructional activities based on educational value rather than novelty alone.

- *Importance for Curriculum and Assessment*

The study may provide insights into integrating formative assessment activities into science teaching. Quizzes, matching exercises, diagram labelling, puzzles and short learning challenges can provide opportunities to assess students' understanding continuously. Such activities may help teachers identify learning difficulties, provide timely feedback and plan suitable remedial instruction.

- *Importance for Educational Research*

This study may add to the existing body of knowledge on gamification-based teaching and academic achievement in science education. It may provide classroom-based evidence regarding the effectiveness of structured game-design elements in teaching biological concepts. The study may also serve as a reference for future researchers interested in investigating gamification across different subjects, classes, educational settings and learner groups.

- *Practical Significance*

The proposed gamification-based intervention is designed to be practical, economical and adaptable to ordinary classroom conditions. Teachers can use cell diagrams, flashcards, worksheets, coloured cards, points charts, badges and simple quiz activities to conduct the intervention. Digital applications and online platforms may also be incorporated when available. However, access to digital devices and the internet is not essential for implementing the proposed activities.

Overall, the present study is significant because it seeks to examine an innovative and practical approach to science teaching. It may provide useful insights into improving students' academic achievement through active participation, meaningful practice, continuous feedback and structured classroom learning experiences.

III. THEORETICAL FRAMEWORK

The present study is based on established motivational and educational theories that explain how goal-setting, feedback, reinforcement and active participation contribute to the learning process. Gamification is not an independent learning theory; rather, it is an instructional design approach that incorporates selected game-design elements into the teaching-learning process. Its application can be understood through motivational, behavioural, constructivist and active learning perspectives. These theoretical perspectives provide a basis for examining the effectiveness of gamification-based Science teaching on the academic achievement of secondary school students.

- *Self-Determination Theory*

Self-Determination Theory, developed by Deci and Ryan, emphasises three basic psychological needs that influence human motivation: autonomy, competence and relatedness. Autonomy refers to having opportunities for choice and participation in learning activities. Competence involves experiencing a sense of achievement through successfully completing appropriately challenging tasks. Relatedness refers to developing meaningful relationships and connections with others.

In gamification-based Science teaching, these principles can be incorporated through learning missions, progressive challenges, constructive feedback and collaborative team activities. Students may experience competence when they complete tasks successfully and receive informative feedback. Team-based missions may promote relatedness through cooperation and peer

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interaction. Providing limited choices in activities may also support autonomy. In the present study, these principles will guide the organisation of classroom activities to encourage meaningful participation and support learning.

➢ *Behaviourist Perspective and Reinforcement*

The behaviourist perspective emphasises the role of reinforcement, feedback and consequences in shaping learning-related behaviour. According to this perspective, appropriate reinforcement can encourage the repetition of desirable learning behaviours.

In gamification-based Science teaching, points, badges and levels may serve as forms of recognition for students' participation, effort, task completion and progress. For example, students may receive an achievement badge for correctly identifying cell organelles or completing a cell-structure activity. Immediate feedback can help students identify errors and improve their responses.

However, rewards will not be treated as the sole basis of learning. Greater emphasis will be placed on conceptual understanding, consistent effort, improvement and the development of scientific knowledge. Thus, the behaviourist perspective provides a theoretical basis for using recognition and feedback as supportive elements in classroom instruction.

➢ *Constructivist Perspective*

Constructivism considers learners as active participants who construct knowledge by connecting new information with their existing knowledge and experiences. Learning becomes meaningful when students explore concepts, interpret information, solve problems and develop their own understanding with appropriate guidance.

In the present study, gamified activities such as cell-structure puzzles, organelle-function matching, classification tasks, diagram interpretation and problem-solving missions will provide opportunities for students to engage actively with scientific concepts. These activities will encourage students to organise information, establish relationships between cell components and understand their functions.

The teacher will act as a facilitator by guiding discussions, clarifying difficult concepts and correcting misconceptions. The constructivist perspective therefore supports the use of interactive and problem-centred activities for developing a better understanding of the chapter “The Fundamental Unit of Life”.

➢ *Experiential and Active Learning Perspective*

Experiential and active learning perspectives emphasise learning through participation in meaningful activities and reflection on the learning experience. Students develop understanding when they engage in tasks that require them to apply knowledge, respond to questions, discuss ideas and interpret information.

Gamification-based Science teaching provides opportunities for such active engagement through quizzes, puzzles, team challenges, learning missions and diagram-based activities. Students can apply their knowledge of cell structures and functions while completing these tasks. Immediate feedback enables them to recognise errors, reconsider their responses and improve their understanding.

In the present study, these principles will guide the organisation of classroom activities that provide opportunities for students to participate, practise and apply the concepts of the selected Science chapter.

➢ *Conceptual Framework of the Study*

The conceptual framework presents the relationship between the independent variable, the learning processes involved and the dependent variable. The independent variable is Gamification-Based Science Teaching, which includes learning missions, points, badges, levels, quizzes, puzzles, team challenges and immediate feedback.

These instructional elements are expected to support learning processes such as active participation, repeated retrieval and practice, goal orientation, task persistence, peer discussion, feedback and self-monitoring. These processes may contribute to the development of students' understanding of scientific concepts.

The dependent variable is academic achievement in the chapter “The Fundamental Unit of Life”. It will be assessed through a researcher-developed achievement test covering knowledge of cell structure, understanding of cell components and their functions, comparison of plant and animal cells, interpretation of cell diagrams and application of scientific concepts.

➢ *Conceptual Framework*

- *Independent Variable: Gamification-Based Science Teaching*

✓ Learning missions and quests
✓ Points and badges
✓ Levels and progress tracking
✓ Quizzes and puzzles
✓ Team challenges
✓ Immediate corrective feedback

- *Learning Processes*

✓ Active participation
✓ Repeated retrieval and practice
✓ Goal orientation and task persistence
✓ Feedback and correction
✓ Peer discussion and collaboration
✓ Monitoring of learning progress

- *Dependent Variable: Academic Achievement*

Academic achievement in The Fundamental Unit of Life, assessed through:

✓ Knowledge of cell structure
✓ Understanding of cell components and their functions
✓ Comparison of plant and animal cells

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- ✓ Interpretation of cell diagrams
- ✓ Application of scientific concepts

This framework provides the theoretical and conceptual foundation for examining whether gamification-based Science teaching produces better academic achievement than conventional teaching among secondary school students.

IV. REVIEW OF RELATED LITERATURE

Reviewing related literature provides a foundation for the present investigation. It brings together earlier theoretical contributions and research on gamification and its use in education. This review helps explain the nature of gamification, its influence on the teaching-learning process and its possible contribution to students' academic achievement. The review focuses on key concepts, previous research findings and their relevance to science education.

➢ *Studies Related to the Concept of Gamification*

Deterding, Dixon, Khaled and Nacke (2011), in their work *From Game Design Elements to Gamefulness: Defining Gamification*, explained gamification as the use of game-design elements in non-game contexts. Their contribution provided a conceptual foundation for understanding gamification and distinguishing it from complete game-based learning. The study is relevant to the present investigation because it supports the integration of selected game elements into regular classroom teaching without replacing the prescribed curriculum or the teacher's instructional role.

➢ *Studies Related to Gamification in Education*

Hamari, Koivisto and Sarsa (2014), in their review *Does Gamification Work? A Literature Review of Empirical Studies on Gamification*, examined 24 empirical studies relating to gamification. Their review indicated that gamification produced positive outcomes in many of the studies. However, the authors also observed that its effectiveness depended on the context, the users and the particular game-design elements employed. They highlighted the importance of appropriate implementation and further rigorous research. This review suggests that gamification should be planned according to students' learning needs and specific instructional objectives.

➢ *Studies Related to Academic Achievement*

Sailer and Homner (2020) conducted a meta-analysis titled The Gamification of Learning: A Meta-analysis. The study examined the effects of gamification on cognitive, motivational and behavioural learning outcomes. The findings indicated statistically significant positive effects across all three categories, although the effects varied in magnitude. This study provides an important research basis for investigating the relationship between gamification and academic achievement. It also indicates the need to examine gamification within specific educational contexts rather than assuming that the same outcomes will occur in every classroom.

➢ *Studies Related to Student Engagement and Learning*

Zainuddin, Chu, Shujahat and Perera (2020), in their systematic review titled *The Impact of Gamification on Learning and Instruction: A Systematic Review of Empirical Evidence*, examined research on the application of gamification in educational settings. Their review identified three important themes: student engagement and motivation, academic achievement, and social connectivity. The authors also discussed variations and contradictions in the available research. Their findings highlight the importance of connecting game-design elements with instructional objectives and meaningful learning activities. This review supports the need to investigate the academic contribution of carefully designed gamification-based classroom instruction.

➢ *Educational Relevance of the Reviewed Literature*

The reviewed works provide a conceptual and research-based foundation for the application of gamification in education. They indicate that learning missions, points, badges, challenges, quizzes and feedback can be incorporated into classroom instruction to organise learning activities around clear goals and progressive tasks. However, the effectiveness of gamification depends on the selection of appropriate elements, their connection with learning objectives and the manner in which they are implemented.

In the present study, gamification elements will be integrated into the teaching of *The Fundamental Unit of Life*. Activities such as cell-structure puzzles, organelle-function matching, diagram-based tasks, quizzes and team challenges will be connected directly with the prescribed Science content. These activities will be supported by teacher explanation, discussion, diagrams and written practice. Academic achievement will be assessed through a researcher-developed achievement test.

➢ *Research Gap*

The reviewed literature indicates that gamification has been investigated across different educational settings, subjects, learning environments and outcome measures. However, the findings also highlight the importance of context-specific investigations and systematic implementation. There is a need for further classroom-based research focusing on the teaching of specific Science content at the secondary school level.

In particular, the present study focuses on Class IX students and the Science chapter "The Fundamental Unit of Life". It proposes to compare gamification-based Science teaching with conventional teaching through a quasi-experimental pre-test–post-test non-equivalent control group design. Academic achievement will be measured using a content-aligned achievement test. Thus, the study seeks to contribute context-specific evidence regarding the effectiveness of gamification-based teaching in secondary school Science education.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

➢ *Objectives of the Study*

The present study has the following objectives:

- To assess the pre-test academic achievement of Class IX students in the Science chapter "The Fundamental Unit of Life".
- To develop and implement gamification-based instructional activities for teaching *The Fundamental Unit of Life* to Class IX students.
- To assess the post-test academic achievement of Class IX students following the implementation of gamification-based Science teaching.
- To compare the pre-test and post-test academic achievement scores of students in the experimental group.
- To compare the pre-test and post-test academic achievement scores of students in the control group.
- To compare the academic achievement of students in the experimental and control groups with reference to their pre-test scores, post-test scores and improvement in achievement.

➢ *Hypotheses of the Study*

The present study will test the following null hypotheses at the 0.05 level of significance:

- H_{01}: There is no significant difference between the pre-test and post-test academic achievement scores of students in the experimental group.
- H_{02}: There is no significant difference between the pre-test and post-test academic achievement scores of students in the control group.
- H_{03}: There is no significant difference between the pre-test academic achievement scores of students in the experimental and control groups.
- H_{04}: There is no significant difference between the post-test academic achievement scores of students in the experimental and control groups.

V. RESEARCH METHODOLOGY

The research methodology describes the systematic procedures adopted to conduct the present investigation. It includes the method of research, research design, population, sample, intervention procedure, research tools, validity and reliability, control of extraneous variables and statistical techniques.

➢ *Method of Research*

The present study will use an experimental research method with a quasi-experimental approach to examine the effectiveness of gamification-based Science teaching on the academic achievement of secondary school students. Since existing classroom groups may be used, individual students will not be randomly assigned to the experimental and control groups.

The experimental group will receive Science instruction through gamification-based activities, whereas the control group will receive conventional teaching. Both groups will be taught the same chapter, *The Fundamental Unit of Life*, with the same learning objectives.

➢ *Research Design*

The study will employ a pre-test–post-test non-equivalent control group design. This design is appropriate when intact classroom groups are used without random assignment of individual students.

Initially, both groups will be administered an academic achievement pre-test. Subsequently, the experimental group will receive gamification-based Science teaching, while the control group will receive conventional instruction. After completing the intervention, both groups will be administered the same or an equivalent academic achievement post-test.

Table 1 Research Design

Group	Pre-test	Instructional treatment	Post-test
Experimental group	Achievement test	Gamification-based Science teaching	Achievement test
Control group	Achievement test	Conventional teaching	Achievement test

➢ *Population of the Study*

The study population will comprise students in Class IX in secondary schools following the Karnataka State Board curriculum. The investigation will focus on students studying the Science chapter "The Fundamental Unit of Life".

➢ *Sample of the Study*

A sample of 60 Class IX students is proposed for the study from a suitable secondary school, subject to school permission and the availability of intact classroom groups. The sample will consist of 30 students in the experimental group and 30 students in the control group.

Table 2 Sample of the Study

Group	Proposed number of students
Experimental group	30
Control group	30
Total	60

➢ *Duration and Procedure of the Intervention*

The proposed intervention will be conducted over a period of six weeks, with two instructional sessions per week, making a total of twelve sessions. The duration may be adjusted according to the school timetable and the time required to complete the selected chapter.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

The experimental group will be taught through gamification-based activities such as learning missions, quizzes, puzzles, points, badges, levels and team challenges. The control group will receive conventional classroom instruction covering the same Science content.

Both groups will receive comparable instructional time and will be taught the same learning objectives to ensure reasonable consistency in the teaching-learning process.

➢ *Tools Used for the Study*

The following tools and instructional materials will be used for the present investigation.

- *Science Achievement Test*

A researcher-developed Science Achievement Test will be prepared based on the chapter "The Fundamental Unit of Life". It will be used to assess students' academic achievement before and after the intervention. The test will contain 25 items, carrying a total of 25 marks.

The test may include multiple-choice questions, matching items, cell-diagram labelling, short-answer questions, and questions based on understanding and application.

- *Gamification-Based Instructional Materials*

The following instructional materials will be prepared for implementing gamification-based Science teaching:

✓ Learning mission cards.
✓ Points and badges charts.
✓ Levels and progress-tracking charts.
✓ Cell-structure diagrams.
✓ Organelle-function matching cards.
✓ Science quizzes and puzzles.
✓ Team challenge activities.
✓ Immediate feedback prompts.

These materials will be designed in accordance with the learning objectives and concepts of the selected chapter.

- *Lesson Plans*

Separate lesson plans will be prepared for the experimental and control groups. The lesson plans will cover the same content and learning objectives. The experimental group's lesson plans will incorporate gamification elements, whereas the control group's lesson plans will follow conventional teaching procedures.

➢ *Validity and Reliability of the Tool*

The Science Achievement Test will be developed by the investigator using a content blueprint covering the major concepts of the chapter "The Fundamental Unit of Life".

➢ *Control of Extraneous Variables*

Efforts will be made to control extraneous variables that may influence students' academic achievement. The following measures will be considered:

- Both groups will be taught the same Science chapter and learning objectives.
- Comparable instructional time will be provided to both groups.
- The same or equivalent achievement tests will be administered to both groups.
- Classroom conditions and teaching schedules will be maintained as consistently as possible.
- Students' attendance and completion of instructional sessions will be recorded.
- Gamification-based instructional materials will be used only with the experimental group during the intervention.

➢ *Statistical Techniques Used*

The data collected will be analysed using appropriate descriptive and inferential statistical techniques. The following statistical techniques are proposed:

- Mean: To determine the average academic achievement scores of students in the experimental and control groups.
- Standard Deviation: To examine the variability in students' achievement scores.
- Independent-Samples t-test: To compare the academic achievement scores and gain scores of the experimental and control groups.
- Paired-Samples t-test: To compare the pre-test and post-test academic achievement scores within each group.
- The level of significance will be fixed at 0.05.

VI. IMPLEMENTATION OF THE GAMIFICATION INTERVENTION

The gamification-based teaching intervention will be implemented systematically among the students in the experimental group. The selected instructional content will be the Class IX Science chapter "The Fundamental Unit of Life". The proposed intervention will be conducted over six weeks, with two instructional sessions per week, making a total of twelve sessions.

The teacher-researcher will introduce the gamification framework, explain the classroom rules and organise learning activities according to the prescribed learning objectives. The game elements will be integrated with regular classroom instruction to make the learning process interactive, purposeful and academically meaningful.

➢ *Orientation and Formation of Learning Teams*

At the beginning of the intervention, students will be introduced to the "Cell Explorer Challenge." The teacher will explain that students will progress through a series of learning missions related to the structure and functions of cells.

Students may be organised into small, balanced teams for selected collaborative activities. Team formation will be planned to encourage equal participation without labelling students according to their academic ability. Each team may select a name related to cell science, such as "Nucleus Navigators," "Organelle Investigators" or "Cell Champions."

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The teacher will explain the points system, badges, levels and expectations associated with the activities. Points will be awarded for correct scientific responses, task completion, improvement, clear explanations and constructive teamwork. Speed alone will not determine achievement. Students will also be given opportunities to correct their mistakes after receiving feedback. The main emphasis will remain on understanding scientific concepts and achieving the intended learning outcomes.

➢ *Division of Learning Content*

For systematic implementation, the selected chapter will be organised into five connected learning missions.

- *Mission 1 – Discovering the Cell*

✓ Meaning and concept of a cell.
✓ Cell as the basic structural and functional unit of life.
✓ Historical background of cell discovery.
✓ Basic organisation of a cell.

- *Mission 2 – Cell Boundary and Movement of Substances*

✓ Plasma membrane and its functions.
✓ Selectively permeable nature of the plasma membrane.
✓ Diffusion and osmosis.
✓ Cell wall and its role in plant cells.

- *Mission 3 – Nucleus and Cytoplasm*

✓ Structure and functions of the nucleus.
✓ Nuclear membrane and chromosomes.
✓ Role of cytoplasm in cellular activities.

- *Mission 4 – Cell Organelles*

✓ Endoplasmic reticulum.
✓ Golgi apparatus.
✓ Lysosomes.
✓ Mitochondria.
✓ Plastids.
✓ Vacuoles.
✓ Structure and functions of important cell organelles.

- *Mission 5 – Cell Comparison and Application*

✓ Differences between plant and animal cells.
✓ Prokaryotic and eukaryotic cells, where included in the prescribed textbook.
✓ Interpretation and labelling of cell diagrams.
✓ Application of concepts related to cell structure and functions.

The content and terminology will be checked against the prescribed Karnataka State Board textbook before preparing the instructional materials. Only the concepts included in the prescribed chapter and relevant learning outcomes will be covered in the intervention and achievement test.

➢ *Game Elements and Classroom Rules*

The following game elements will be incorporated into the instructional process:

Table 3 Game Elements and Classroom Rules

Game element	Classroom use
Missions / quests	A sequence of curriculum-linked tasks related to each subtopic.
Points	Points are awarded for correct answers, task completion, improvement and clear explanations.
Badges	Badges recognise achievements such as Cell Structure Explorer, Organelle Expert and Diagram Detective.
Levels	Students progress from identification to explanation, comparison and application.
Quizzes	Short retrieval-practice activities conducted at the end of a lesson or mission.
Puzzles and matching	Matching organelles with their functions and assembling and labelling cell diagrams.
Team challenges	Collaborative tasks that involve discussion and the development of a shared answer.
Feedback	Immediate explanations of errors, with opportunities to retry or improve.

The points system will be transparent and consistently applied throughout the intervention. Students may receive points for providing correct answers, explaining scientific concepts, completing activities and demonstrating improvement after feedback.

Badges will recognise different forms of achievement so that students with varied strengths have opportunities to experience success. Public ranking will be avoided or used cautiously to prevent embarrassment and unnecessary competition. The teacher will maintain a supportive classroom environment in which learning and improvement are given greater importance than winning.

➢ *Conduct of the Learning Missions*

Each instructional session will follow a systematic procedure:

- Introduction: The teacher will begin the session with a short recap, question or activity to connect the new concept with students' previous knowledge.
- Concept Explanation: The relevant Science concept will be explained with the support of the textbook, diagrams, models, charts or other teaching-learning materials.
- Mission Activity: Students will participate in the assigned mission individually or in teams.
- Interaction and Discussion: Students will discuss their responses, share ideas and provide explanations.

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- Feedback and Correction: The teacher will review the responses, clarify misconceptions and provide immediate corrective feedback.
- Progress Recognition: Points, badges or progress records will be updated according to the established rules.
- Session Closure: The session will conclude with a short quiz, exit question or reflection to check individual understanding.

This procedure will ensure that game elements remain connected with the prescribed Science content and do not become separate entertainment activities.

➢ *Illustrative Gamified Activities*

The following activities will be used during the intervention:

- Cell Parts Match-Up: Students will match the names of cell structures with their respective functions. This activity will help them recall and understand the functions of different cell components.
- Cell Diagram Detective: Students will identify incorrectly labelled parts in a given cell diagram and make the necessary corrections. This activity will develop their ability to interpret and understand cell diagrams.
- Organelle Mystery Cards: Students will read clues describing the functions of different cell organelles and identify the corresponding organelles.
- Build-a-Cell Challenge: Teams will arrange labelled cards or cut-outs to construct a plant or animal cell diagram. This activity will help students understand the arrangement and organisation of cell components.
- Plant-versus-Animal Cell Challenge: Students will classify given statements and cell structures into plant-cell and animal-cell categories and explain their answers.
- Cell Mission Quiz: Students will answer questions arranged at different levels of difficulty, progressing from basic identification to understanding and application.
- Exit Ticket: At the end of selected sessions, each student will answer a short individual question related to the concept taught. This will help the teacher check individual understanding and ensure that team performance does not replace individual learning evidence.

➢ *Evaluation and Reflection*

Students' learning will be monitored throughout the intervention using oral questions, worksheets, diagram-labelling activities, matching exercises, short quizzes and mission-completion tasks.

These formative assessment activities will help the teacher identify students' difficulties, provide timely feedback and modify explanations wherever necessary. The teacher-researcher will also maintain records of completed activities, student participation and implementation of the planned instructional sessions.

These formative assessments will guide classroom instruction, but they will not replace the formal academic achievement pre-test and post-test used in the study.

➢ *Six-Week Intervention Schedule*

The proposed intervention schedule consists of two instructional sessions per week over a period of six weeks.

Table 4 Six-Week Intervention Schedule

Week	Planned Science content and gamified activities	Expected learning outcomes
First	Orientation; introduction to the cell; Mission 1; team names, rules and progress chart.	Identify the cell as the basic unit of life and recall basic cell concepts.
Second	Mission 2; plasma membrane, diffusion, osmosis and cell wall; membrane sorting challenge.	Explain the role of the cell boundary and distinguish the cell membrane from the cell wall.
Third	Mission 3; nucleus, chromosomes and cytoplasm; nucleus clue cards and diagram labelling.	Identify the nucleus and describe its major functions.
Fourth	Mission 4A; endoplasmic reticulum, Golgi apparatus and lysosomes; organelle-function matching.	Relate selected organelles to their functions.
Fifth	Mission 4B and 5; mitochondria, plastids, vacuoles and plant and animal cell comparison; Build-a-Cell challenge.	Explain organelle functions and compare plant and animal cells.
Sixth	Consolidation; mixed-level quiz, cell diagram puzzle, application questions and revision mission.	Integrate chapter concepts and prepare for the post-test.

- Frequency of Intervention: Two sessions per week.
- Duration: Six weeks.
- Total Number of Sessions: Twelve sessions.

The duration of each session will follow the school timetable and will be recorded during the implementation of the intervention. The schedule may be adjusted according to the pace of the class while ensuring that all planned learning objectives are covered.

➢ *Instruction for the Control Group*

The control group will be taught the same Science chapter, *The Fundamental Unit of Life*, through conventional teaching methods during the corresponding period.

The instructional process may include:

- Teacher explanation of scientific concepts.
- Textbook reading and discussion.
- Blackboard or whiteboard explanation.
- Drawing and interpretation of cell diagrams.
- Question-and-answer sessions.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

- Note-taking and written exercises.
- Revision of important concepts.

The control group will not receive the planned gamification package during the intervention. However, both groups will be provided with comparable instructional time and will cover the same prescribed content and learning objectives. This arrangement will help maintain reasonable consistency between the two groups.

➢ *Administration of the Post-Test*

After the completion of the six-week intervention, the students in both the experimental and control groups will be administered the academic achievement post-test.

The same achievement test or an equivalent validated test form will be used for both groups under similar testing conditions. If the same test is administered, the possibility of a practice effect will be considered while interpreting the results.

The responses will be evaluated according to the predetermined marking scheme. The scores obtained by the students will be recorded systematically for statistical analysis. Confidentiality of student information will be maintained, and the collected data will be used exclusively for the purposes of the research.

The pre-test and post-test scores will subsequently be analysed using appropriate statistical techniques to examine changes in academic achievement within each group and differences between the experimental and control groups.

VII. ANALYSIS AND INTERPRETATION

- Hypothesis 1: There is no significant difference between the pre-test and post-test academic achievement scores of students in the experimental group.

Table 5 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	0.0000000035	Significant
Post-test	30	20.77	3.80			

The data in the table show that the mean pre-test academic achievement score of the experimental group was 17.50, with a standard deviation of 5.01. After the implementation of gamification-based Science teaching, the mean post-test score increased to 20.77, with a standard deviation of 3.80. The mean difference between the pre-test and post-test scores was 3.27 marks.

The calculated paired-samples t-value was 10.279, and the corresponding p-value was 0.0000000035, which is less than the 0.05 level of significance. Hence, the difference between the pre-test and post-test academic achievement scores is statistically significant. Therefore, the null hypothesis (H_{01}), which states that there is no significant difference between the pre-test and post-test academic achievement scores of students in the experimental group, is rejected.

These findings indicate that the students demonstrated a statistically significant improvement in academic achievement following the implementation of gamification-based Science teaching.

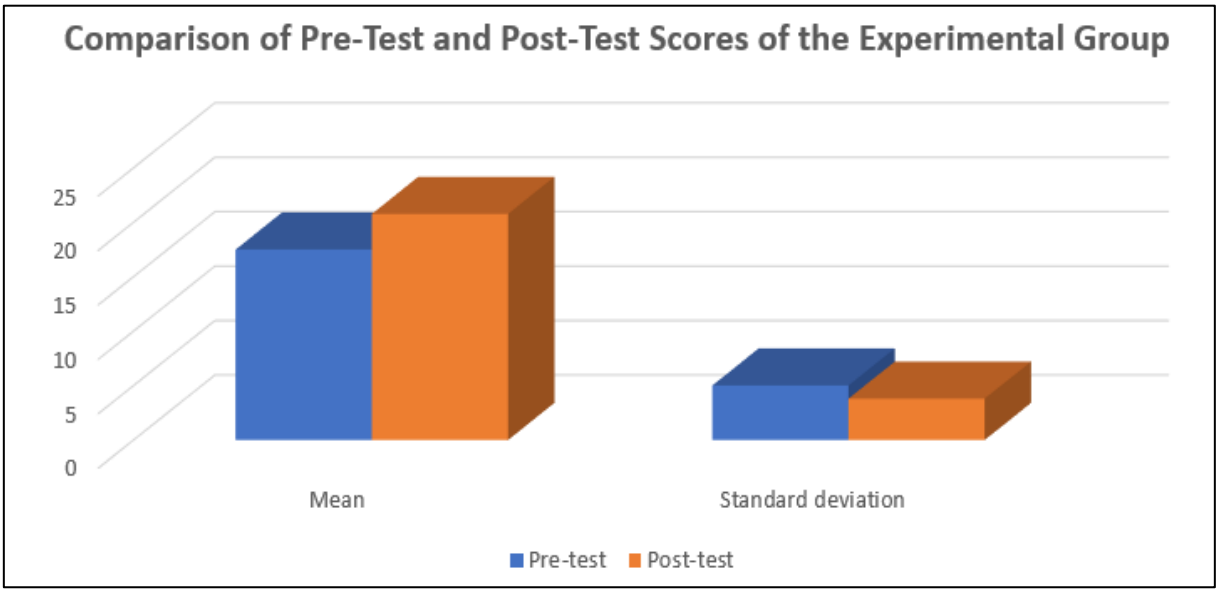


Fig 1 Comparison of Pre-Test and Post-Test Scores of the Experimental Group

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

- Hypothesis 2: There is no significant difference between the pre-test and post-test academic achievement scores of students in the control group.

Table 6 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			

The data in the table show that the mean pre-test academic achievement score of the control group was 17.47, with a standard deviation of 5.17. The mean post-test score increased slightly to 17.67, with a standard deviation of 5.05. The mean difference between the pre-test and post-test scores was 0.20 marks.

The calculated paired-samples t-value was 1.361, and the corresponding p-value was 0.184, which is greater than the 0.05 level of significance. Hence, the difference between the pre-test and post-test academic achievement scores is not statistically significant. Therefore, the null hypothesis (H_{02}) is not rejected.

These findings indicate that there was no statistically significant improvement in the academic achievement of students in the control group following conventional Science teaching.

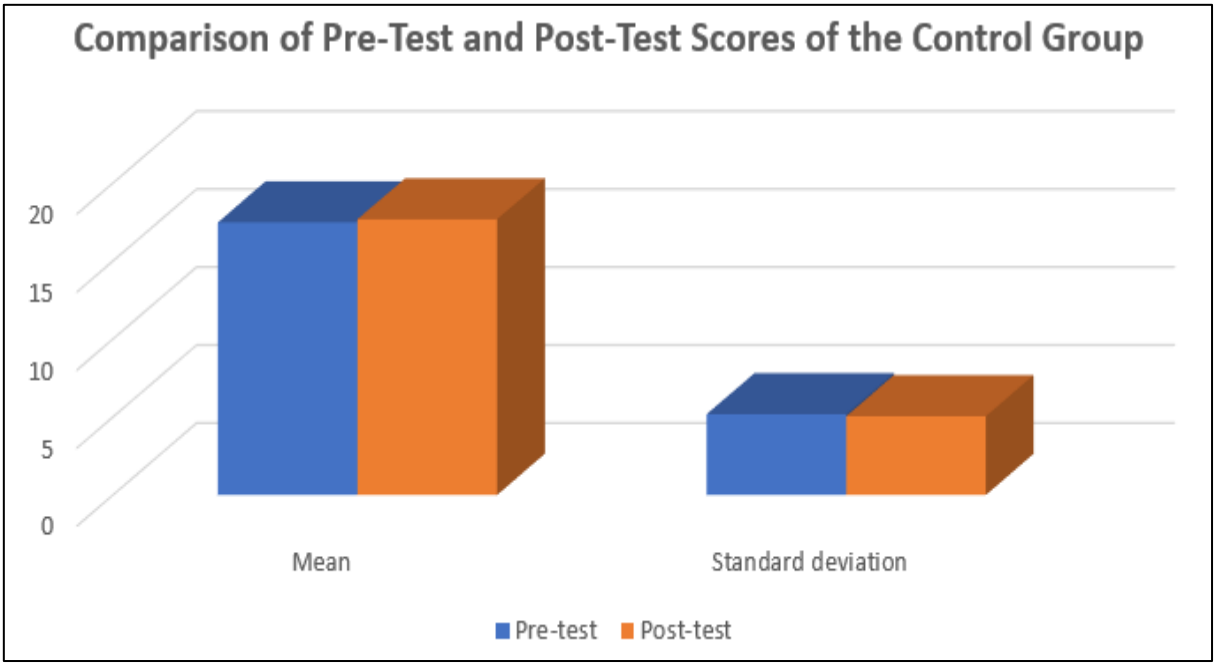


Fig 2 Comparison of Pre-Test and Post-Test Scores of the Control Group

- Hypothesis 3: There is no significant difference between the pre-test academic achievement scores of students in the experimental and control groups.

Table 7 Comparison of Pre-Test Academic Achievement 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			

The data in the table show that the mean pre-test academic achievement score of the experimental group was 17.50, with a standard deviation of 5.01. The mean pre-test score of the control group was 17.47, with a standard deviation of 5.17.

The calculated independent-samples t-value was 0.025, and the corresponding p-value was 0.980, which is greater than the 0.05 level of significance. Hence, the difference between the pre-test academic achievement scores of the experimental and control groups is not statistically significant. Therefore, the null hypothesis (H_{03}) is not rejected.

These findings indicate that both groups had nearly equal academic achievement levels before the implementation of the intervention. Thus, the two groups were comparable in terms of their initial academic achievement.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

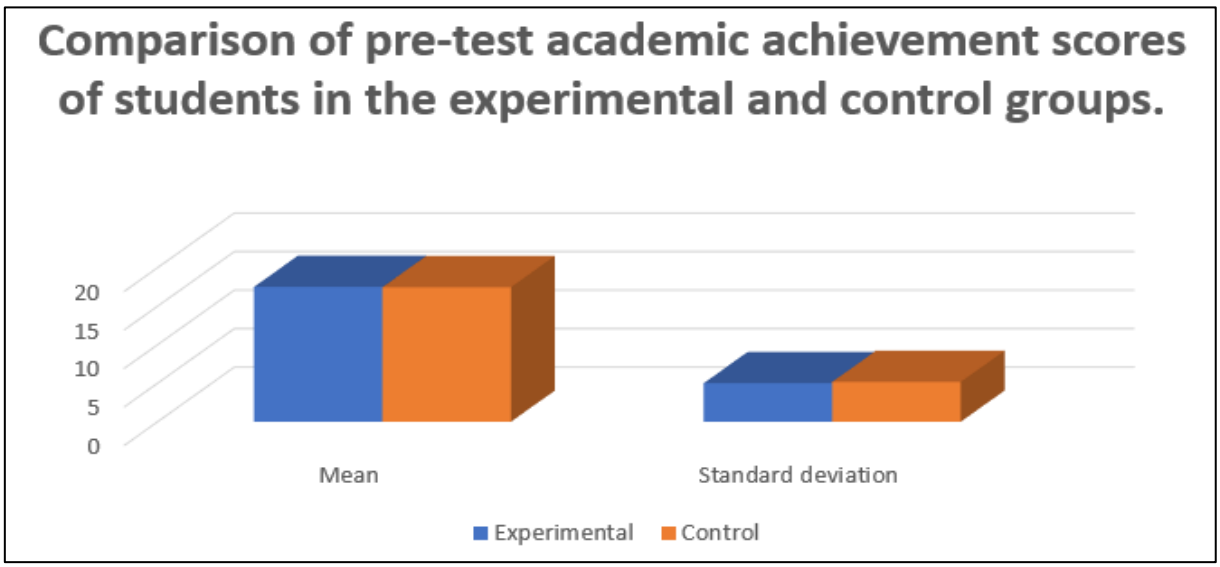


Fig 3 Comparison of Pre-Test Academic Achievement Scores of Students in the Experimental and Control Groups.

- Hypothesis 4: There is no significant difference between the post-test academic achievement scores of students in the experimental and control groups.

Table 8 Comparison of Post-Test Academic Achievement 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			

The data in the table show that the mean post-test academic achievement score of the experimental group was 20.77, with a standard deviation of 3.80. The mean post-test score of the control group was 17.67, with a standard deviation of 5.05.

The calculated independent-samples t-value was 2.687, and the corresponding p-value was 0.0094, which is less than the 0.05 level of significance. Hence, the difference between the post-test academic achievement scores of the experimental and control groups is statistically significant. Therefore, the null hypothesis (H_{04}) is rejected.

These findings indicate that the experimental group obtained a significantly higher mean academic achievement score than the control group after the intervention. This suggests that gamification-based Science teaching may be more effective in improving students' academic achievement than conventional teaching in the selected chapter, The Fundamental Unit of Life.

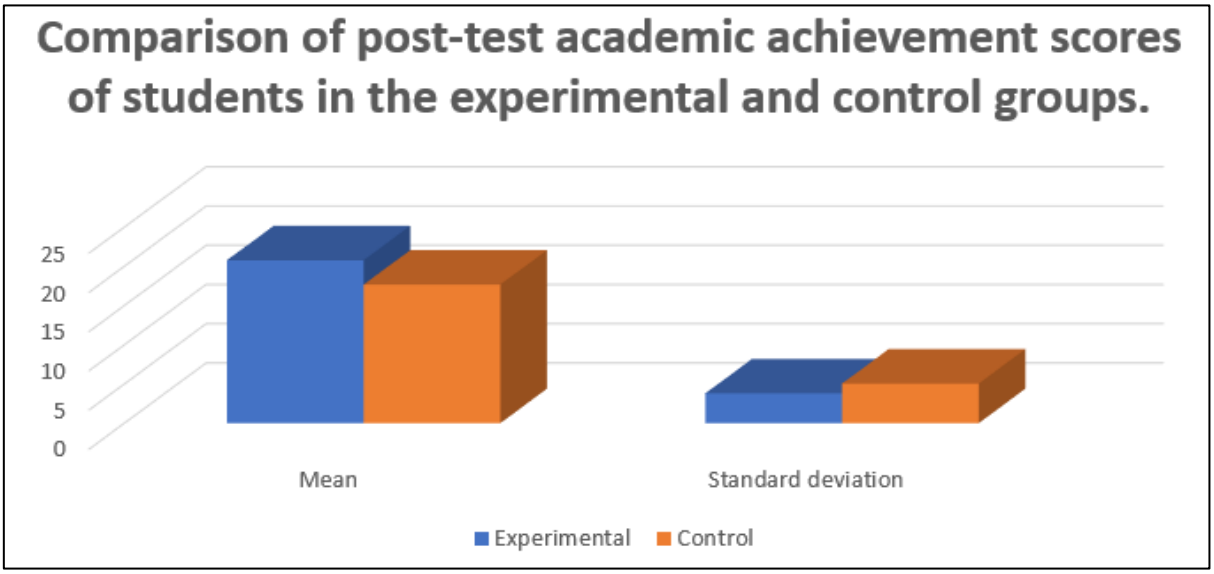


Fig 4 Comparison of Post-Test Academic Achievement Scores of Students in the Experimental and Control Groups.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

VIII. FINDINGS OF THE STUDY

- A statistically significant difference was found between the pre-test and post-test academic achievement scores of students in the experimental group. Students demonstrated higher academic achievement after receiving gamification-based Science teaching.
- There was no statistic significant difference was found between the pre-test and post-test academic achievement scores of students in the control group.
- There was no statistic significant difference was found between the pre-test academic achievement scores of students in the experimental and control groups, indicating that both groups had nearly equal initial achievement levels.
- A statistically significant difference was found between the post-test academic achievement 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.
- A statistically significant difference was found between the mean gain scores of the experimental and control groups. The experimental group demonstrated greater improvement in academic achievement than the control group.

IX. DISCUSSION OF THE FINDINGS

The present study examined the effectiveness of gamification-based Science teaching on the academic achievement of Class IX students in the chapter "The Fundamental Unit of Life". The findings revealed that students who received gamification-based instruction demonstrated greater improvement in academic achievement than those who received conventional teaching. The results are discussed in relation to the objectives, hypotheses and theoretical foundations of the study.

➢ *Improvement in Academic Achievement of the Experimental Group*

The findings showed a statistically significant difference between the experimental group's pre-test and post-test academic achievement scores. The mean score increased from 17.50 in the pre-test to 20.77 in the post-test, with a calculated t-value of 10.279 and a p-value of less than 0.001.

This improvement may be attributed to the systematic integration of gamification elements such as learning missions, points, badges, levels, quizzes, puzzles and team challenges. These activities provided opportunities for students to actively participate in the learning process, practise scientific concepts and receive immediate feedback. The findings are consistent with the principles of Self-Determination Theory, which emphasises competence, autonomy and relatedness as important factors in motivation. This result also supports the relevance of active and constructivist learning approaches in science education.

➢ *Academic Achievement of the Control Group*

The findings indicated that the difference between the pre-test and post-test academic achievement scores of students in the control group was not statistically significant. The mean score increased slightly from 17.47 to 17.67, with a calculated t-value of 1.361 and a p-value of 0.184.

This suggests that conventional teaching did not produce a statistically significant improvement in the academic achievement scores of the control group during the study period. Although teacher explanation, textbook reading, diagrams and written exercises are important instructional practices, the findings suggest that the additional interactive learning opportunities provided through gamification may have contributed to the greater improvement observed in the experimental group.

➢ *Comparability of the Experimental and Control Groups*

A comparison of the pre-test academic achievement scores showed no statistically significant difference between the experimental and control groups. The experimental group obtained a mean score of 17.50, while the control group obtained a mean score of 17.47. The calculated t-value was 0.025, with a p-value of 0.980.

This indicates that both groups had nearly equal academic achievement levels before the implementation of the intervention. The similarity in their initial achievement scores provides a useful basis for examining the differences observed after the intervention. However, the use of intact classroom groups means that other initial differences cannot be completely ruled out.

➢ *Comparison of Post-Test Academic Achievement Scores*

A comparison of the post-test scores showed a statistically significant difference between the experimental and control groups. The experimental group obtained a mean score of 20.77, whereas the control group obtained a mean score of 17.67. The calculated t-value was 2.687, with a p-value of 0.0094.

The experimental group demonstrated higher academic achievement than the control group after the intervention. This finding suggests that gamification-based Science teaching may provide additional learning benefits when compared with conventional classroom instruction. The use of progressive missions, quizzes, puzzles and feedback may have helped students recall, understand and apply the concepts related to cell structure and functions.

➢ *Comparison of Improvement in Academic Achievement*

The comparison of gain scores revealed that the experimental group recorded a mean improvement of 3.27 marks, whereas the control group recorded a mean improvement of 0.20 marks. The difference in improvement was statistically significant (Welch's $t = 8.758$, $p < 0.001$).

This finding indicates that the improvement in academic achievement was considerably greater among students who received gamification-based Science teaching. The result provides further support for the potential usefulness of

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gamification as an instructional approach for teaching scientific concepts at the secondary school level.

➢ *Relationship with Previous Research*

The findings of the present study are broadly consistent with the research reviews conducted by Hamari, Koivisto and Sarsa (2014), Sailer and Homner (2020), and Zainuddin, Chu, Shujahat and Perera (2020). These works reported that gamification can produce positive learning-related outcomes, although its effectiveness depends on the instructional context and the manner in which game elements are implemented.

The present study adds a classroom-based investigation focusing specifically on the academic achievement of Class IX students in the Science chapter "The Fundamental Unit of Life". These findings suggest that integrating curriculum-related missions, quizzes, puzzles, team activities and immediate feedback into regular teaching can support students' academic learning.

➢ *Overall Discussion*

The overall findings suggest that gamification-based Science teaching has the potential to improve academic achievement among secondary school students. The intervention provided students with structured learning goals, opportunities for repeated practice, constructive feedback and interactive classroom experiences. These features may have contributed to better understanding and retention of the selected Science concepts.

The findings also highlight the importance of designing gamified activities according to curriculum requirements rather than using game elements merely for entertainment. The teacher's role in explaining concepts, guiding activities, correcting misconceptions and providing feedback remains essential. Therefore, gamification should be viewed as a supportive instructional approach that complements effective classroom teaching.

X. EDUCATIONAL IMPLICATIONS

The findings of the present study highlight the potential of gamification-based Science teaching in improving the academic achievement of secondary school students. The study suggests that integrating game-design elements into regular classroom instruction can provide meaningful learning opportunities. The major educational implications of the study are outlined below.

- Promotion of Active Learning: Teachers should incorporate interactive activities such as quizzes, puzzles, missions and challenges to encourage students' active participation in the Science classroom.
- Improvement in Academic Achievement: Gamification-based teaching may be used as a supplementary instructional approach to strengthen students' understanding of scientific concepts and improve their academic achievement.
- Making Science Learning Interesting: Teachers should use curriculum-related game elements to make difficult and abstract Science concepts more accessible, interesting and meaningful to students.
- Development of Conceptual Understanding: Activities such as cell-diagram labelling, organelle-function matching and problem-solving missions can help students understand the structure and functions of different cell components.
- Use of Immediate Feedback: Teachers should provide timely and constructive feedback through quizzes, worksheets and classroom activities so that students can identify mistakes and improve their understanding.
- Encouragement of Collaborative Learning: Team challenges and group-based missions can provide opportunities for students to share ideas, discuss scientific concepts and learn from one another.
- Support for Individual Learning Progress: Points, badges and progress charts can be used to recognise students' efforts, improvement and task completion while encouraging continuous participation.
- Promotion of Innovative Teaching Practices: Teacher education institutions should provide opportunities for prospective teachers to develop skills in planning and implementing innovative instructional approaches such as gamification.
- Integration of Low-Cost Teaching-Learning Materials: Schools can implement gamification-based activities using charts, flashcards, worksheets, diagrams, coloured cards and classroom boards without depending entirely on expensive digital equipment.
- Strengthening Formative Assessment: Teachers can use short quizzes, exit tickets, matching activities and mission-based tasks to assess students' understanding continuously and identify areas requiring additional explanation.

Overall, the study highlights the importance of adopting learner-centred, interactive and activity-based approaches in science education. Gamification-based teaching can serve as a useful supplementary instructional strategy for creating an engaging classroom environment and supporting students' academic achievement.

XI. SUGGESTIONS FOR FURTHER RESEARCH

The present study examined the effectiveness of gamification-based Science teaching on the academic achievement of Class IX students in the chapter "The Fundamental Unit of Life". Based on the scope and limitations of the study, the following suggestions are offered for further research.

- Larger Sample: Similar studies may be conducted with a larger sample of secondary school students to examine the effectiveness of gamification-based teaching across different educational settings.
- Different Geographical Areas: Further research may be undertaken in different districts, regions and states to examine whether the findings are consistent across diverse educational contexts.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov422

- Different School Types: Similar investigations may be conducted in government, aided and private schools to compare the effectiveness of gamification-based Science teaching.
- Different Class Levels: Further studies may be conducted among students of Classes VIII, IX and X to examine the effectiveness of gamification at different stages of secondary education.
- Different Science Topics: The effectiveness of gamification-based teaching may be investigated in other Science topics such as force and motion, chemical reactions, electricity, natural resources and life processes.
- Comparison of Different Teaching Methods: Future researchers may compare gamification-based teaching with other innovative instructional approaches such as project-based learning, inquiry-based learning, flipped classroom and cooperative learning.
- Digital and Non-Digital Gamification: Comparative studies may be conducted to examine the effectiveness of technology-supported gamification and low-cost non-digital gamification activities in science education.
- Long-Term Effectiveness: Further research may examine the long-term retention of scientific concepts through delayed post-tests to determine whether the academic benefits of gamification are sustained over time.
- Different Student Characteristics: Future studies may examine whether the effectiveness of gamification-based teaching varies according to students' previous academic achievement, learning background or other relevant educational characteristics.
- Replication Using Improved Research Designs: Further studies may use larger samples, appropriate random assignment where feasible, multiple schools and stronger statistical procedures to provide more robust evidence regarding the effectiveness of gamification-based Science teaching.

These suggestions may help researchers explore the educational value of gamification in different subjects, school contexts and instructional settings. Further investigations can contribute to developing effective, inclusive and innovative teaching practices for improving the quality of science education.

XII. CONCLUSION

The present study examined the effectiveness of gamification-based Science teaching on the academic achievement of Class IX students in the chapter “The Fundamental Unit of Life”. The study was conducted using a quasi-experimental pre-test–post-test non-equivalent control group design with 60 students divided into experimental and control groups.

The findings revealed a statistically significant improvement in the academic achievement of students in the experimental group following the implementation of gamification-based Science teaching. The mean achievement score increased from 17.50 in the pre-test to 20.77 in the post-test. In contrast, the control group showed only a slight improvement, from 17.47 to 17.67, which was not statistically significant.

The comparison of pre-test scores indicated that both groups had nearly equal academic achievement levels before the intervention. However, the post-test comparison revealed a statistically significant difference between the experimental and control groups, with the experimental group obtaining a higher mean score. The comparison of gain scores also demonstrated significantly greater improvement in the experimental group.

These findings suggest that integrating learning missions, points, badges, levels, quizzes, puzzles, team challenges and immediate feedback into science instruction can provide meaningful learning opportunities. These activities encourage active participation, repeated practice, conceptual understanding and constructive classroom interaction.

The study highlights the importance of adopting innovative, learner-centred and activity-based approaches in secondary school Science education. Gamification-based teaching can serve as a useful supplementary instructional strategy when it is carefully planned and aligned with curriculum objectives. The teacher's role in explaining concepts, guiding activities and correcting misconceptions remains essential.

In conclusion, gamification-based Science teaching demonstrated promising results in improving the academic achievement of Class IX students in *The Fundamental Unit of Life*. The study supports the integration of appropriate gamification elements into regular classroom instruction to make Science learning more interactive, meaningful and effective. However, further research involving larger samples, different school settings and stronger research designs is necessary to establish the wider applicability of these findings.

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