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Beyond the Lab Coat: A Comparative Study of Teaching Methodologies in Interdisciplinary Science

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A B S T R A C T

This study investigates the effectiveness of different teaching methodologies in an interdisciplinary setting that bridges traditional subject boundaries. The research aims to identify the most impactful strategies for diverse student populations, addressing various types of learners—aural, visual, and kinaesthetic. We employed a mixed-methods approach utilizing four primary teaching methodologies: expository lecture, hands-on practical sessions, ICT tools, and the use of realia to ground abstract concepts in tangible objects for better comprehension of a topic common to both Chemistry and Biology. Central to the approach the study embraces the modern educational paradigm where teachers are facilitators of knowledge rather than mere transmitters. We also integrated peer learning to foster collective problem- solving skills and facilitate interexpertise through the collaborative sharing of good practices. The core pedagogical approach was structured to guide the students through a learning journey from the known to unknown and from easy to complex, breaking down complex concepts into understandable portions. The ultimate goal was to decrease rote learning and instead promote deep understanding and conceptual clarity. The curriculum was designed to cultivate factual knowledge, critical thinking, and creative problem-solving skills which ensures a strong practical skill set. Teaching was tailored to be professionally and vocationally directed, ensuring students not only learn but apply knowledge meaningfully by shifting the focus from passive memorization to active, career-ready competence. In a nutshell, the study evaluates the relative effectiveness of each methodology across learner types, identifying best practices that foster engagement, autonomy, and higher-order thinking.

Keywords: Interdisciplinary, Types of learners, teaching methodologies, Teachers are facilitators, Peer learning, Interexpertise, known to unknown, easy to complex

INTRODUCTION

In today's fast-paced, technology-driven world, STEM education has become more crucial than ever in preparing students for future challenges and careers. Its interdisciplinary approach fosters critical thinking and problem-solving, yet one of the persistent obstacles in STEM teaching lies in effectively communicating complex scientific concepts to a diverse student population which consists of different types of learners. Traditional teaching methods dominated by lectures and rote memorization—often fail to engage learners with different cognitive strengths, such as visual, auditory, and kinaesthetic modalities. This shortfall becomes especially problematic in subjects that demand an integrated understanding of multiple disciplines, such as the study of biomolecules and nucleic acids, which require the simultaneous application of knowledge and deep understanding of the subjects. Many students find themselves overwhelmed, disengaged, or unable to form deep conceptual links due to a lack of tailored instructional strategies. This issue is not only a barrier to academic success but also a contributor to the broader challenge of STEM attrition, particularly among under-represented or struggling learners. To address these challenges, this paper proposes a multi-modal, student-centred teaching methodology rooted in STEM principles. Thus four different teaching methodologies-Realia, comprehensive lectures, hands-on experiments and ICT tools were used for three different types of learners to develop subject-matter fluency. A variety of ICT Tools used were the learning management system-Smart board, educational app – Kahoot, VR, and AR simulations for DNA and RNA structures to ensure better understanding, for clarity of concepts, catering to the needs of different types of learners. By aligning content delivery with varied learning preferences and actively engaging students through interactive and interdisciplinary tools, this approach aims to enhance comprehension, sustain interest, and make advanced topics more accessible and meaningful for all learners. This study aims to solve problems such as the Limitations of Traditional Teaching Methods, Insufficient Emphasis on Active Learning Strategies, Failure to Accommodate Diverse Learning Styles in general, Failure to bridge theoretical insight with real-world needs, and Insufficient evaluation of Comprehensive Learning, which affects a larger section of students. These need to be worked upon to ensure a secure and strong educational foundation leading to great development ahead for a better nation.

RESEARCH METHODOLOGY

This study was conducted to observe the effectiveness of different teaching methodologies applied on different types of learners in understanding and getting a grasp of the concept of Nucleic Acid in the context of both Biology and Chemistry for Students of class XI. The details are presented below:

Subjects

The class consisted of 10 students of standard XI in the age group of 16 to 17 years. All the students were from educated backgrounds. They were Science students with Biology and Chemistry being their main subjects. This class of students had three types of learners - Visual, Aural and Kinaesthetic. The topic of Nucleic Acids was taught in detail using different teaching methodologies to fulfil the needs of all types of learners in context of both Biology and Chemistry

Teaching method

Four different teaching methodologies were used keeping in mind the different types of learners based on the Chemistry and Biology of the topic Nucleic Acid. Proper teaching sessions were conducted for a week to teach the topic. The following table covers the teaching methodology and tools used for each in all:

TEACHING METHODOLOGY	TOOLS USED FOR THE SPECIFIC TEACHING METHODOLOGY
REALIA	Visual and digital realia: Video clips VR and AR
LECTURE	It is a teacher-centred approach, with the instructor serving as the main source of information, and students taking on a role of listening, asking questions and taking notes.
HANDS-ON EXPERIMENT(PRACTICAL)	Experiment of DNA extraction from banana was conducted in the lab
ICT	Learning management system - Smart board, educational app - Kahoot.

Realia: Bringing the Real World into the Classroom

Realia is a teaching methodology that uses real-life objects and materials to make abstract concepts concrete and relatable for students. Instead of just talking about an object or concept, a teacher brings it into the classroom for students to see, touch, and interact with. This approach is highly effective for kinaesthetic and visual learners, as it provides a multi- sensory experience that enhances engagement and retention. As mentioned in the table, we specifically used visual and digital realia which included video clips showing DNA in real life contexts.

Lecture: The Foundation of Knowledge Transfer

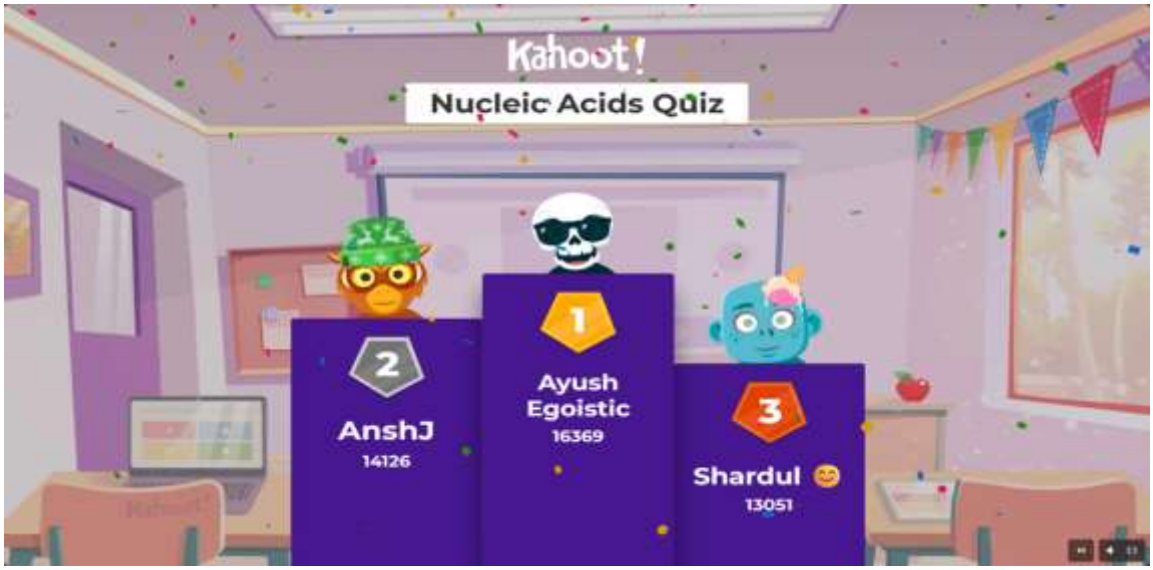
The lecture is a traditional and widely used teaching method where the teacher delivers information verbally to a group of students. It is a teacher-centred approach, ideal for efficiently imparting a large amount of information to a large audience. The teacher acts as the primary source of knowledge, and students are expected to listen, ask questions and take notes. While this method can be less interactive and may not cater to all learning styles, it is highly effective for providing a structured overview of a topic, establishing foundational knowledge, and clarifying complex ideas in a direct, organized way. Thus teacher plays a crucial role as a facilitator and transferring knowledge.

Practical: Learning by Doing

The practical teaching methodology focuses on hands-on experience and the application of theoretical knowledge to real-world situations. This approach moves beyond passive listening and encourages students to actively participate in the learning process through experiments, projects, simulations, and problem-solving tasks. In a Science class it involves conducting lab experiments. DNA extraction from a Banana is a very important and helpful experiment that was performed by the students. Practical learning is crucial for developing critical thinking, problem-solving skills, and a deeper, everlasting understanding of concepts.

ICT: The Digital Age of Education

ICT, or Information and Communication Technology, in education refers to the use of digital tools and devices to enhance the teaching and learning experience. This methodology leverages technology like computers, interactive whiteboards, educational software, and online platforms to create a more dynamic and flexible learning environment. Examples include using a management system to organize course materials and track student progress. ICT caters to modern learners and can be used to create personalized learning paths, making it a versatile tool for engaging students with diverse learning needs. ICT tools such as smart boards, educational apps like Kahoot were used.



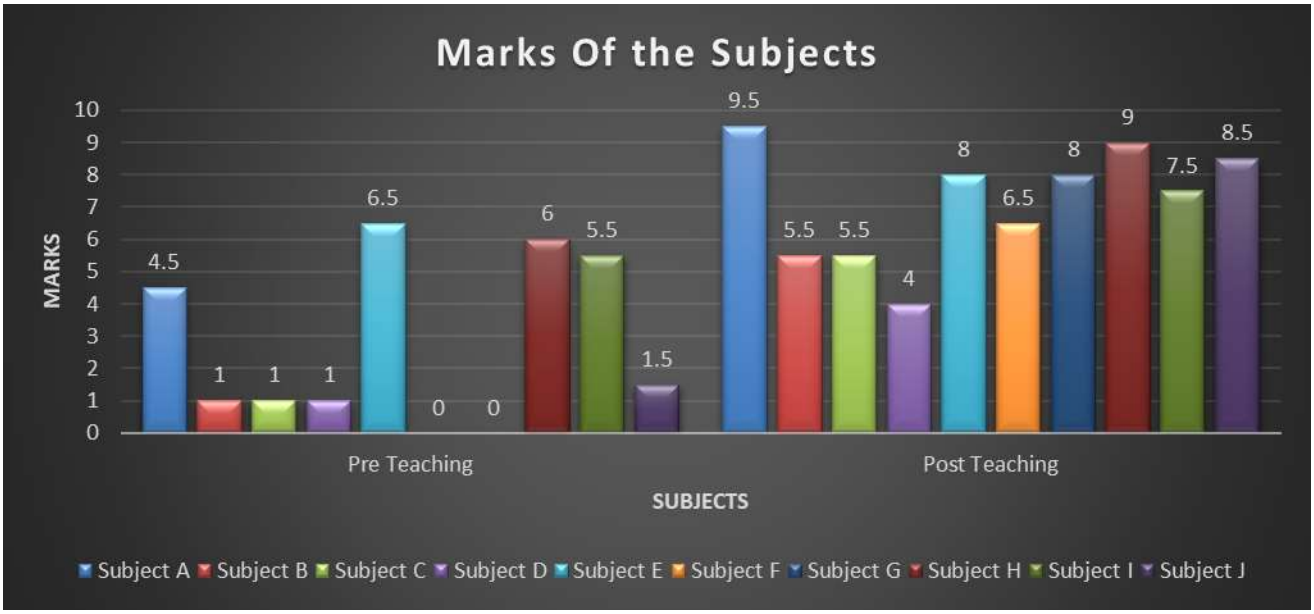
RESULTS AND DISCUSSIONS

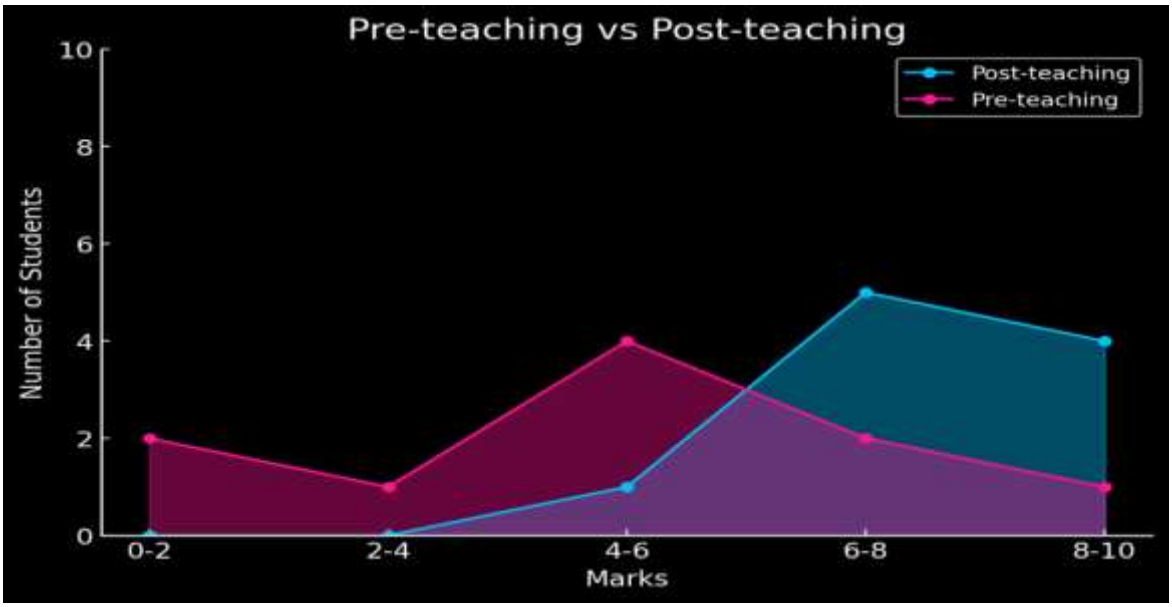
The main purpose of this study was to identify and study the effectiveness of various teaching methodologies in ensuring the understanding of concepts of nucleic acids by students of standard XI. The transition from class X to class XI marks a significant academic lead particularly in the sciences where the depth and complexity of the topics increase substantially. Students are introduced to advanced concepts that lay the foundation for higher education and future scientific inquiry and so is the topic of nucleic acids. Their study is vital as it connects core concepts in genetics, heredity and biotechnology making it an essential area of focus in both subjects of Chemistry and Biology and beyond.

To evaluate the effectiveness of instructional intervention, two assessments each of 10 marks were administered, one prior to the teaching of the topic and another subsequent to its completion. The initial assessment served as a diagnostic tool to gauge students' baseline understanding while the post assessment measured the conceptual gains achieved through targeted teaching which included teaching through different methodologies. The table below

S. No.	NAME OF THE STUDENT	ASSESSMENT 1	ASSESSMENT 2
1	A	4.5	9.5
2	B	01	5.5
3	C	01	5.5
4	D	01	04
5	E	6.5	08
6	F	ZERO	6.5
7	G	ZERO	08
8	H	06	09
9	I	5.5	7.5
10	J	1.5	8.5

summarises the observed progression:





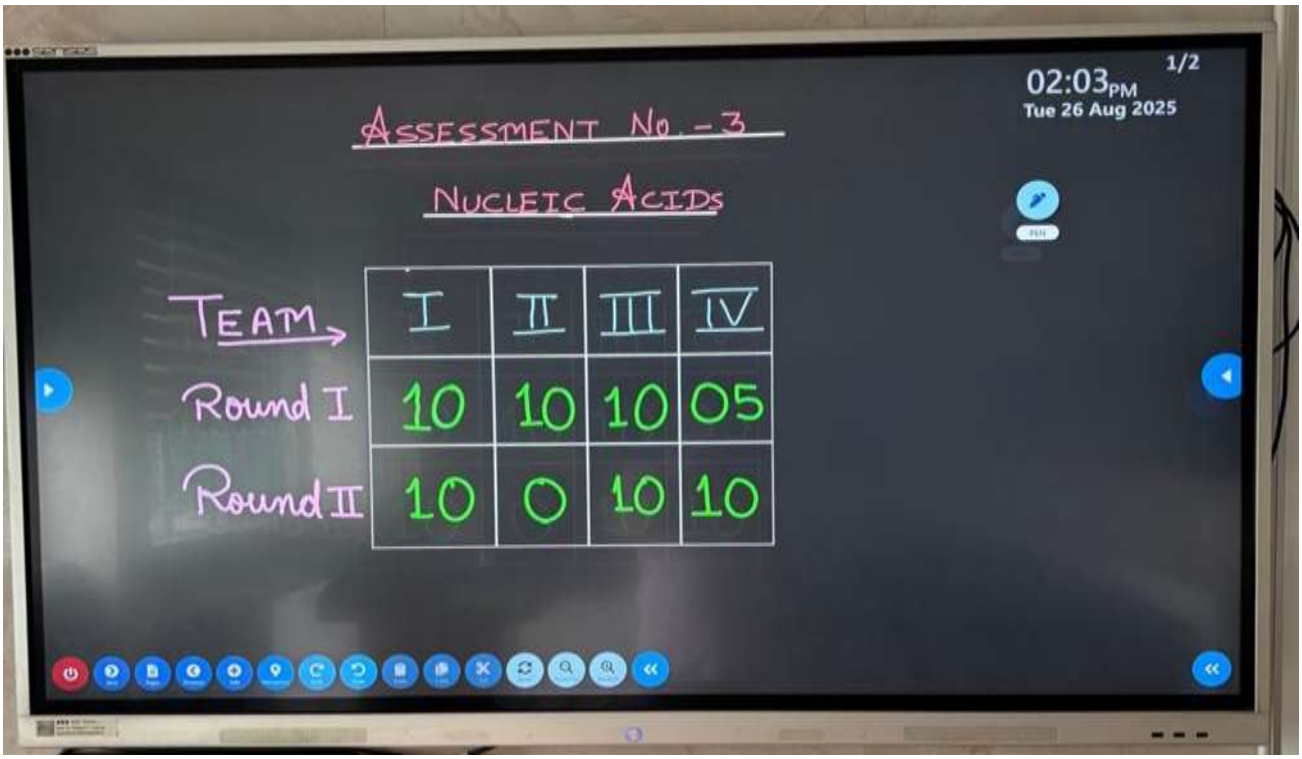
If we take 6 as the benchmark, then the number of students scoring above that changed substantially after the different teaching methodologies.

The above graphs clearly show an impressive improvement in the results, indicating that the teaching methodologies used were successful and effective.

KAHOOT QUIZ

Subject	**Kahoot Score**
A	11828
B	10936
C	11654
D	14126
E	16369

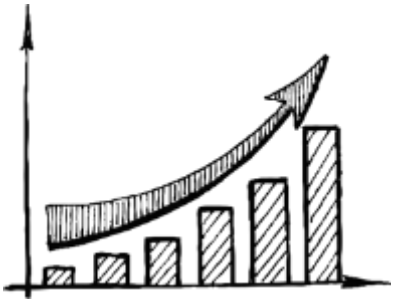
Subject	**Kahoot Score**
F	10843
G	7035
H	13051
I	11410
J	11213



A comparative analysis of the results revealed a marked improvement in performance, indicating a significant enhancement in students' comprehension. After a thorough analysis of the data, the results of this research paper indicate that the integrated STEM-based teaching methodology significantly improved students' understanding and engagement with the complex topic of Nucleic Acids. The findings provide compelling evidence that a diversified instructional approach, which caters to the three primary types of learners—visual, aural, and kinaesthetic—is more effective than a traditional, single-format lecture.

Quantitative Findings: A Clear Improvement

The data collected from post-intervention assessments, including proper assessment and quizzes, revealed a notable increase in student performance. The average score of the final assessment was 7.2, a significant increase from the average score of assessment 1, which was 2.7



The success of this methodology lies in its ability to directly address the identified problems: the lack of accommodation for diverse learning styles, the disconnect between abstract theory and real-world application, and the limitations of traditional assessment. By incorporating tools for visual, auditory, and kinaesthetic learners, we created an environment where students could approach the material from their own unique cognitive perspectives. The qualitative feedback reinforced this, with students reporting that they felt the learning process was tailored to them, leading to a greater sense of ownership over their education.

Summary and Conclusion

The observations showed that there was a significant increase in the level of interest and understanding of the concept of Nucleic Acids among standard XI students. It can be observed and concluded that the different teaching methodologies used have significantly contributed in the improvement of the understanding of the concept by the students, ensuring a strong foundation.

Furthermore, a comparative analysis showed that the students were now more successful in solving complex, application-based problems related to nucleic acids and their functions. This indicates that the new methodology did not just improve memorization of facts but also fostered a deeper conceptual understanding. Beyond the numerical data, the qualitative feedback from student interviews and teacher observations provided valuable insights into the impact of the variety of methodologies used. Students consistently reported feeling more engaged and confident in their ability to understand the subject. Visual learners expressed appreciation for the 3D models and video clips, stating that they made it easier to "see" the abstract structures of DNA. Kinaesthetic learners particularly enjoyed the hands-on experiment, which helped them remember the DNA from the banana better than any textbook could explain. Auditory learners found the group discussions to be highly beneficial, as they learned by both listening to and explaining concepts to their peers.

The teachers also noted a significant increase in classroom participation and a decrease in student frustration. The differentiated approach created an environment where students felt their learning needs were being met, leading to greater motivation and a more positive attitude toward learning Science.

To put it all together the results of this study have significant implications for STEM education, particularly in Biology and Chemistry in accordance to our case study. They confirm the hypothesis that a single teaching methodology is insufficient for a diverse student body. By tailoring instruction to different learning styles, educators can create a more in. The success of this study underscores the importance of integrating practical, hands-on, and technology-driven tools into the curriculum, which not only makes learning more interesting but also aligns with the core principles of STEM education. While this study focused on a specific topic, the methodology can be adapted for other complex subjects. Future research should explore the long-term retention of this knowledge and its impact on students' future academic and career choices.

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