

Comparative analysis of academic performances across online, offline and hybrid modes in STEM education

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Abstract

The rapid integration of digital technologies in education, especially during and after the COVID-19 pandemic, has led to the widespread adoption of online and hybrid learning models alongside traditional face-to-face (offline) instruction. In the context of STEM (Science, Technology, Engineering, and Mathematics) education, where conceptual understanding, problem-solving, and practical engagement are critical, evaluating the effectiveness of different instructional modes has become increasingly important. This study presents a comparative analysis of academic performances across online, offline, and hybrid learning environments in STEM education.

The research examines key performance indicators such as student grades, conceptual comprehension, engagement levels, participation in practical activities, and overall learning outcomes. Data are collected from students enrolled in STEM courses delivered through the three instructional modes, using a combination of academic records, surveys, and structured assessments. Quantitative analysis is complemented by qualitative insights to understand how learning environments influence student motivation, interaction, and accessibility to educational resources.

Preliminary findings suggest that while offline learning often supports stronger engagement in laboratory-based and collaborative activities, online learning provides greater flexibility and access to digital resources. Hybrid learning models appear to balance these advantages by integrating face-to-face instruction with digital tools, potentially leading to improved learning outcomes for diverse groups of students. However, variations in technological infrastructure, digital literacy, and instructional design significantly influence the effectiveness of each mode.

The present study conducted in the Undergraduate Students of Mrinalini Datta Mahavidya pith college of 5th Sem who are continuing their Graduation in Education.

The study highlights the strengths and limitations of online, offline, and hybrid instructional approaches in STEM education and provides recommendations for educators and institutions to optimize teaching strategies. The findings contribute to the ongoing discourse on

technology-enhanced learning and support the development of more effective, inclusive, and resilient STEM education systems.

Key words- Online Education,Offline Education,Hybrid Education,STEM Education

Introduction

The landscape of education has undergone significant transformation with the advancement of digital technologies and the increasing integration of online learning platforms. Traditionally, STEM (Science, Technology, Engineering, and Mathematics) education has relied heavily on face-to-face classroom instruction, laboratory work, and direct interaction between instructors and students. This conventional offline learning mode has long been considered effective for developing analytical thinking, problem-solving abilities, and practical skills that are essential in STEM disciplines. However, the rapid growth of internet accessibility, learning management systems, and digital tools has enabled the expansion of online education, allowing students to access learning materials and participate in academic activities remotely.

The global shift toward online learning was further accelerated during the COVID-19 pandemic, when educational institutions worldwide were compelled to adopt digital platforms to maintain academic continuity. While online learning provided flexibility and broader access to educational resources, it also raised questions regarding student engagement, effectiveness of instruction, and the development of practical competencies, particularly in STEM fields that often require hands-on experimentation and collaborative problem solving. In response to these challenges, many institutions introduced hybrid (or blended) learning models, which combine elements of both online and offline instruction to create a more flexible and interactive learning environment.

Each learning mode—online, offline, and hybrid—offers unique advantages and limitations. Offline learning facilitates direct communication, immediate feedback, and structured classroom environments that can enhance student participation and collaborative learning. Online learning, on the other hand, provides greater accessibility, flexibility in time and location, and the availability of diverse multimedia resources that can support independent learning. Hybrid learning attempts to integrate the strengths of both approaches, enabling institutions to provide face-to-face interaction while also leveraging digital technologies to enhance teaching and learning experiences.

Given the critical role of STEM education in fostering innovation, technological advancement, and economic development, understanding how different instructional modes affect student academic performance is essential. Academic performance in STEM is influenced by multiple factors, including teaching methodologies, learning environments, technological accessibility, and student engagement. Therefore, evaluating the effectiveness of online, offline, and hybrid learning approaches can help educators design more effective instructional strategies and improve learning outcomes.

This study aims to conduct a comparative analysis of academic performance across online, offline, and hybrid learning modes in STEM education. By examining student achievement, engagement levels, and learning experiences across these modes, the research seeks to identify the strengths and challenges associated with each instructional approach. The findings of this study are expected to

provide valuable insights for educators, policymakers, and institutions in developing more effective and adaptive teaching models that enhance the quality of STEM education in an increasingly digital learning environment.

Online Education-

Online education is a flexible ,internet -based learning system that allows students to access courses,materials, and earn degrees or certifications from anywhere,bypassing the need for physical attendance.It uses digital platforms for synchronous (real-time) or asynchronous (self-paced)learning,often featuring video lectures,online quizzes and direct communication with instructors.

Offline Education-

Offline education or traditional in -person learning,involves face-to-face instruction in physical classrooms,fostering immediate interaction,structured schedules,and hands -on,collaborative learning.It builds discipline and minimizes digital distractions but is often more expensive , rigid in scheduling , and requires commuting.

Hybrid Education-

Hybrid learning is an educational model combining in-person classroom instruction with remote online learning, offering flexibility and personalized education. It allows students to engage synchronously—some physically present, others virtual—enabling continuity and access to education regardless of location. This approach requires strong technology infrastructure, teacher training, and supports student autonomy

Hybrid learning, often referred to as blended learning, is an educational approach that combines physical, face-to-face teaching with virtual learning experiences. It allows students to attend a portion of their classes online, giving them the freedom to access course content, complete assignments, and interact with teachers outside traditional classroom hours. This model promotes self-paced learning while maintaining the structure of in-person interactions.

STEM Education –

STEM education is an interdisciplinary approach to teaching learning that integrates science, technology, engineering and mathematics.STEM education primarily focuses on hands on and problem based learning methodology.

STEM education equipped students with the skills that are required to succeed in their respective careers whether it be in jobs ,centre entrepreneurship etc.

Review of literature

Anushka Bhardwaj, Mayank Vashish and Dr.Arora shaveta to study on Analyzing students performance in online, hybrid and offline Mode-A cross -sectional study.This study shows that the future of higher education should in corporate a hybrid approach for a better teaching - learning and quality education.

Priyanka study on A comparative study of offline and online Modes of Learning.This study shows that both offline and online Modes of learning are equally beneficial.In India students are not ready to accept that the online mode of learning can replace the offline mode of learning and they can use the online mode of learning and a complementary mode.

Objectives of the Study

The main objective of this study is to conduct a comparative analysis of academic performance in STEM education across online, offline, and hybrid learning modes. The study aims to understand how different instructional approaches influence students' learning outcomes, engagement, and overall academic achievement.

The specific objectives of the study are as follows:

To compare the academic performance of students in STEM subjects across online, offline, and hybrid modes of learning.

To examine the level of student engagement and participation in each mode of instruction.

To analyze the effectiveness of teaching methodologies used in online, offline, and hybrid STEM education.

To identify the advantages and limitations of each learning mode in supporting conceptual understanding and practical skills in STEM subjects.

To investigate the role of technological accessibility and digital literacy in influencing students' academic performance in online and hybrid learning environments.

To explore students' perceptions and learning experiences regarding different instructional modes in STEM education.

To provide recommendations for educators and institutions to improve teaching strategies and optimize learning outcomes in STEM education across different learning environments.

These objectives guide the research in understanding how different educational delivery modes impact student achievement and help in identifying the most effective approaches for STEM learning.

Research Design

This study adopts a quantitative comparative research design to analyze differences in academic performance among students learning through online, offline, and hybrid modes in STEM education.

A cross-sectional approach is used, where academic performance data from students enrolled in different learning modes are collected and compared at a specific point in time.

The design enables the researcher to:

Measure academic outcomes across learning modes

Identify statistically significant differences

Evaluate the effectiveness of each instructional mode in STEM learning.

Methodology

1. Research Approach

The study follows a deductive research approach, where hypotheses are formulated based on existing theories of digital learning and traditional classroom learning.

Hypotheses have been tested using statistical analysis techniques to determine whether the mode of instruction significantly affects students' academic performances.

2. Population of the Study

The population of the study consists of students enrolled in STEM courses (Science, Technology and Mathematics) in The Mrinalini Datta Mahavidyapith..college of North 24 Parganous District of West Bengal.

The study include students experiencing:

Online learning environments

Traditional face-to-face classroom learning

Hybrid/blended learning environments

3. Sample and Sampling Technique

Sample Size

A sample of 100 students were selected to ensure adequate statistical reliability.

Example distribution:

35 students – Online learning

30 students – Offline learning

35 students – Hybrid learning

Sampling Technique

The study focuses on stratified random sampling.

Students organized group according to their mode of learning (online, offline, hybrid), and participants were randomly selected from each group.

This ensures balanced representation from each instructional mode.

4. Data Collection Methods

Primary Data

Primary data have been collected through:

1. Structured Questionnaire

A questionnaire has assess:

Students' learning experiences

Engagement levels

Perceived effectiveness of learning mode

Access to technology

The questionnaire used a Likert scale (1–5).

2. Academic Performance Records

Students' academic performance has been measured using:

Final exam scores

GPA or percentage

STEM subject grades

These records have obtained with institutional permission.

5. Variables of the Study:

Independent Variable

Mode of learning:

Online

Offline

Hybrid

Dependent Variable

Academic performance indicators:

Test scores

Final grades

GPA in STEM subjects

Control Variables (optional)

Age

Gender

Socioeconomic background

Internet accessibility

Prior academic achievement

6. Data Analysis Techniques

The collected data have been analysed using statistical software such as Excel.

Statistical Methods

Descriptive Statistics

Mean

Standard deviation

Frequency distribution

ANOVA (Analysis of Variance)

To determine whether there are significant differences in academic performance across online, offline, and hybrid learning modes.

To identify which groups differ significantly.

Correlation Analysis (optional)

To examine relationships between engagement, access to technology, and academic performance.

7. Reliability and Validity

Reliability

The reliability of the questionnaire is tested by using Cronbach's Alpha to ensure internal consistency.

Validity

Content validity is ensured by consulting experts in STEM education.

Construct validity will be established by aligning survey questions with learning effectiveness indicators.

8. Ethical Considerations

The study followed ethical research practices:

Participation in voluntary

Informed consent have been obtained from participants

Students' personal data is remaining for confidential

Academic records have been used only for research purposes

9. Limitations of the Study

Possible limitations include:

Variation in teaching quality across institutions

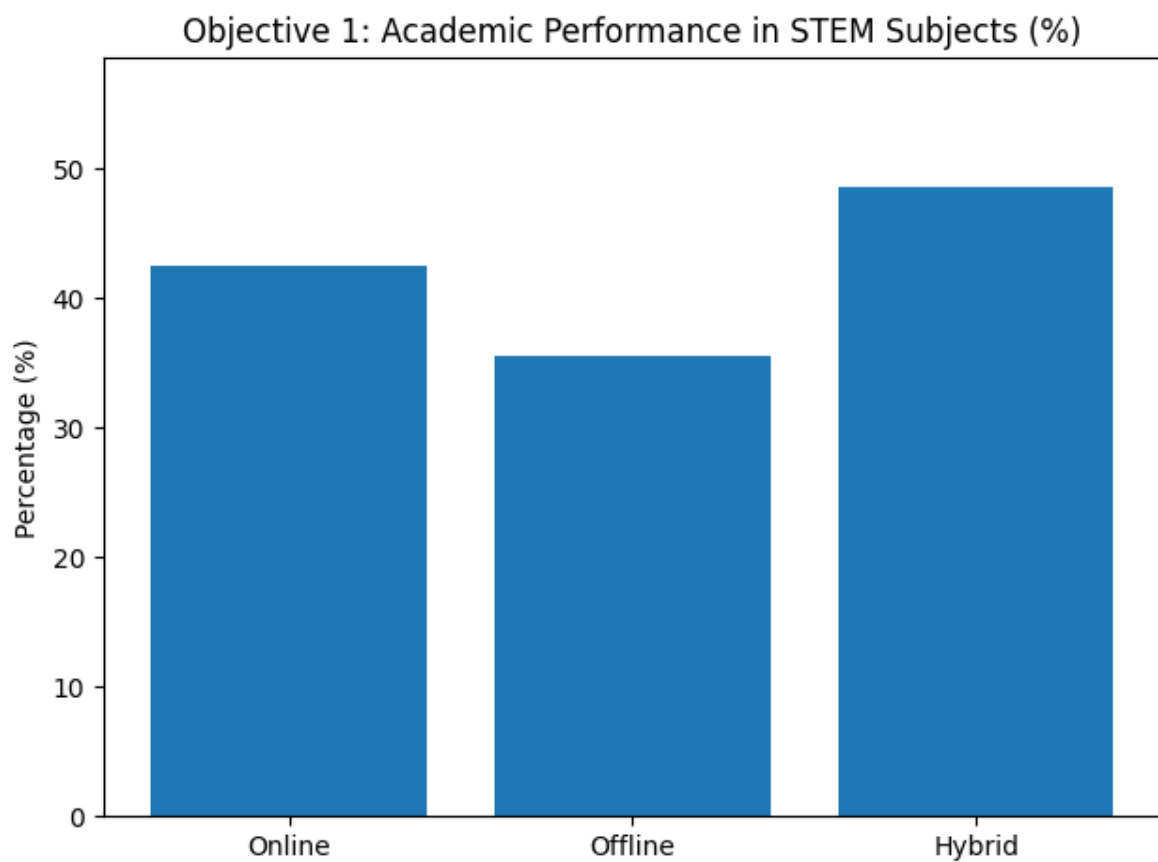
Differences in students internet access .

10. Analysis Of The Study

Objective -1

Academic performance of student in STEM subject -

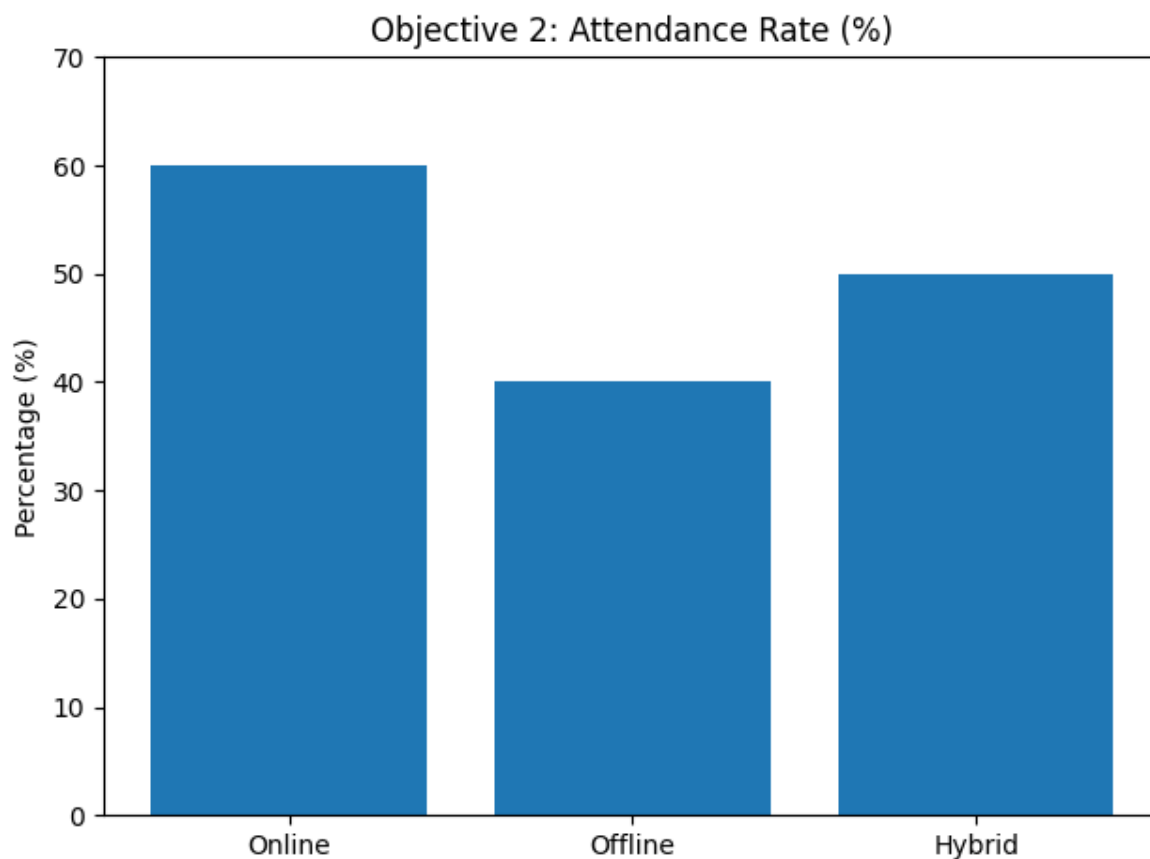
Mode of Learning	Academic Performance (%)
Online	42.5
Offline	35.5
Hybrid	48.5



It can be seen from the table above that academic performance in the case of online classes is 42.5%, offline classes is 35.5%,and hybrid mode classes is 48.5%.

Objective 2

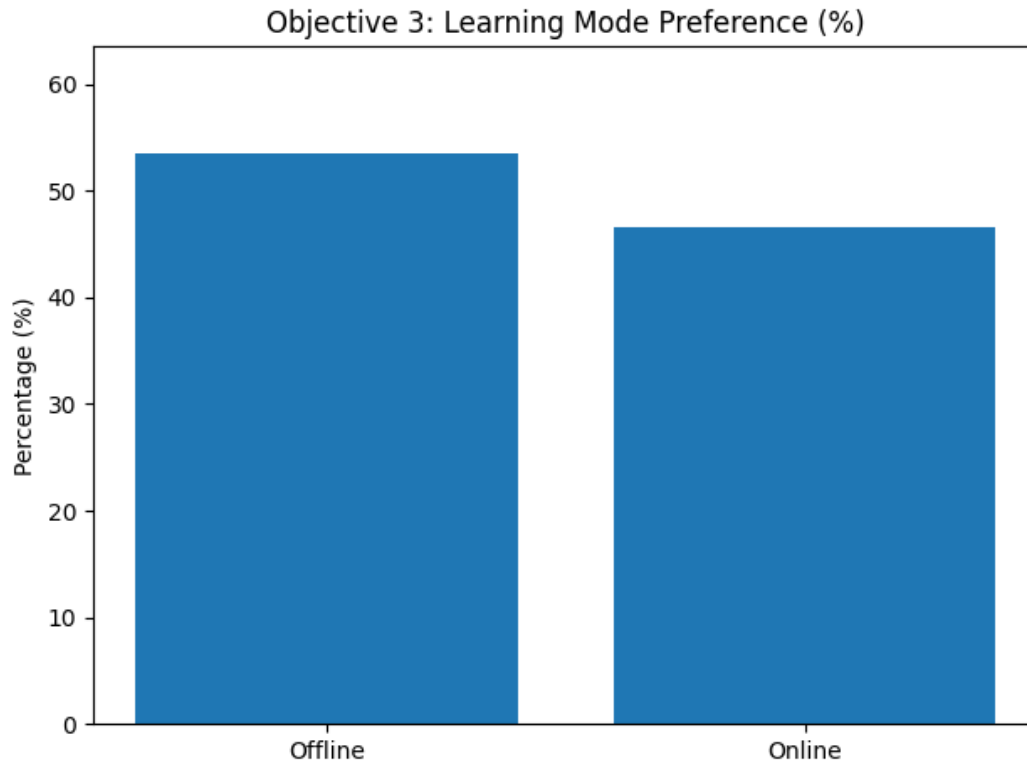
Mode of Learning	Attendance Rate (%)
Online	60
Offline	40
Hybrid	50



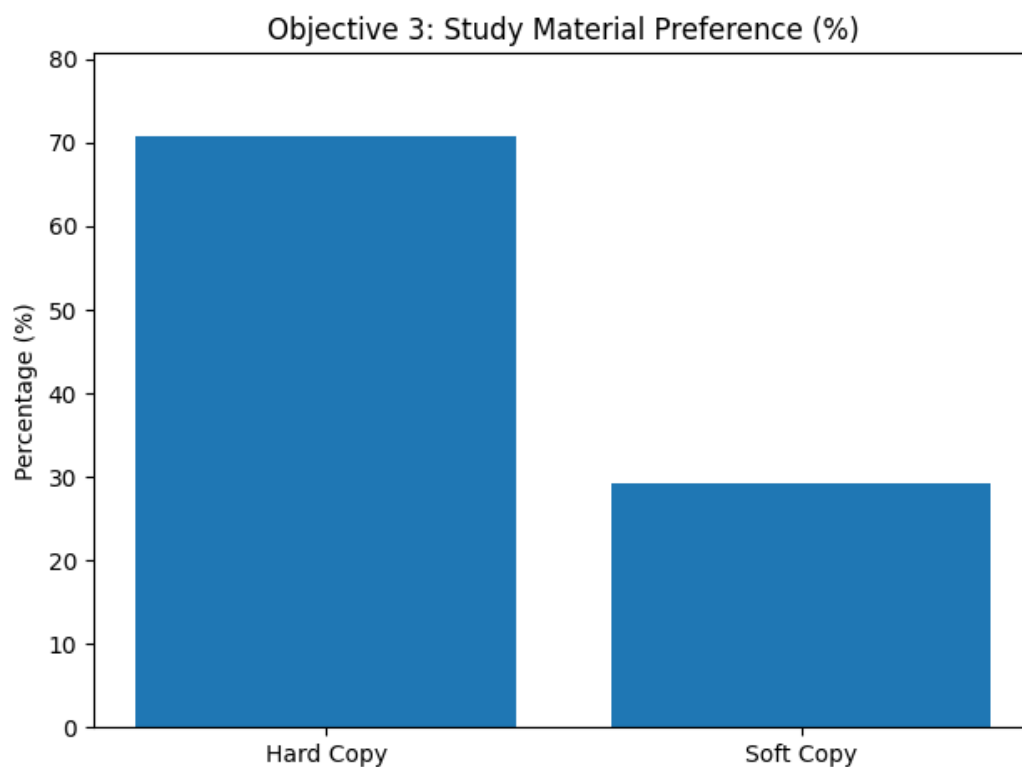
Based on the table above, we can conclude that the attendance rates are highest in the online, offline and hybrid modes specifically: 60% for online classes, 40% for offline classes and 50% for hybrid classes.

Objective 3

Learning Mode	Preference (%)
Offline	53.5
Online	46.5



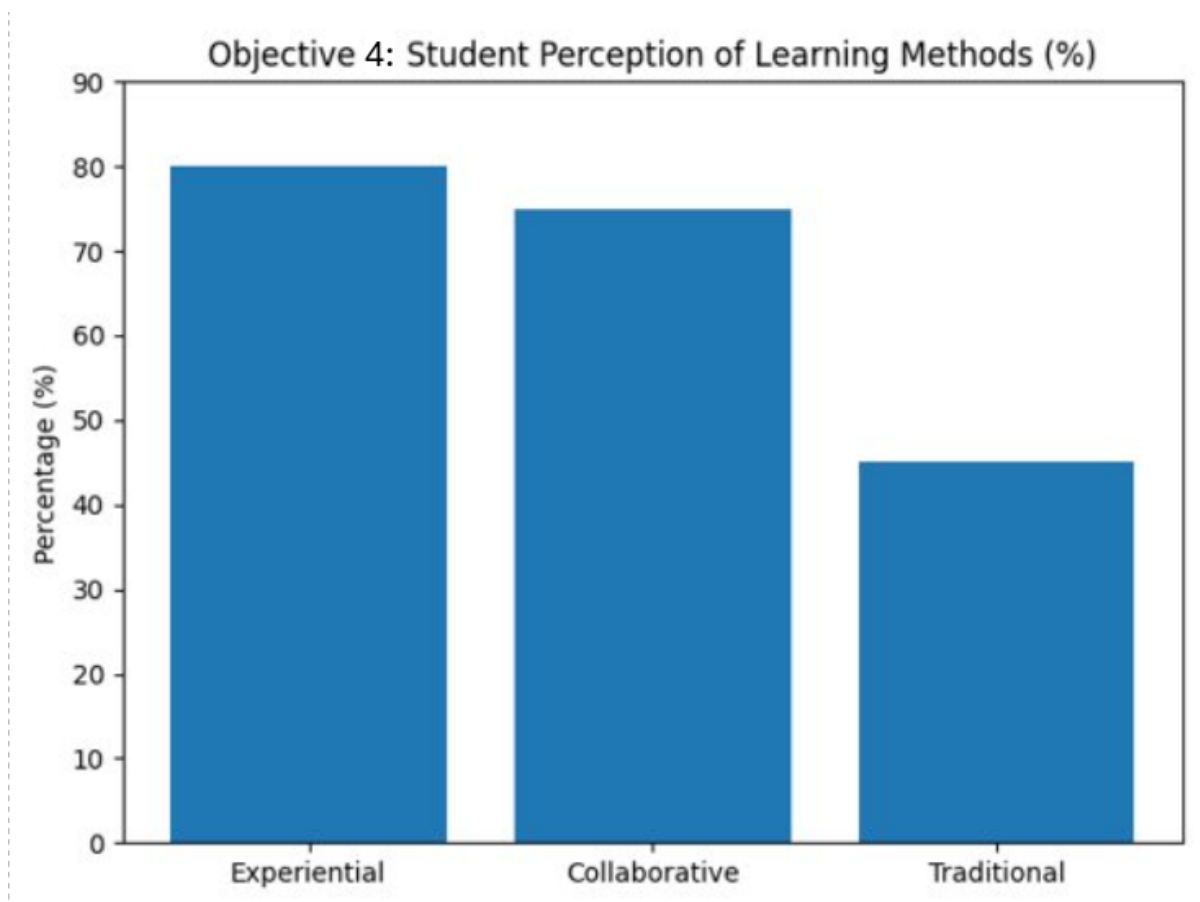
Study Material	Preference (%)
Hard Copy	70.7
Soft Copy	29.3



It shows that 53.5% of students prefer the offline mode of learning and 46.5% of students prefer the online mode of learning. It shows that 70.7% of students prefer hard copies of study materials and 29.3% of students prefer soft copies of study materials.

Objective 4

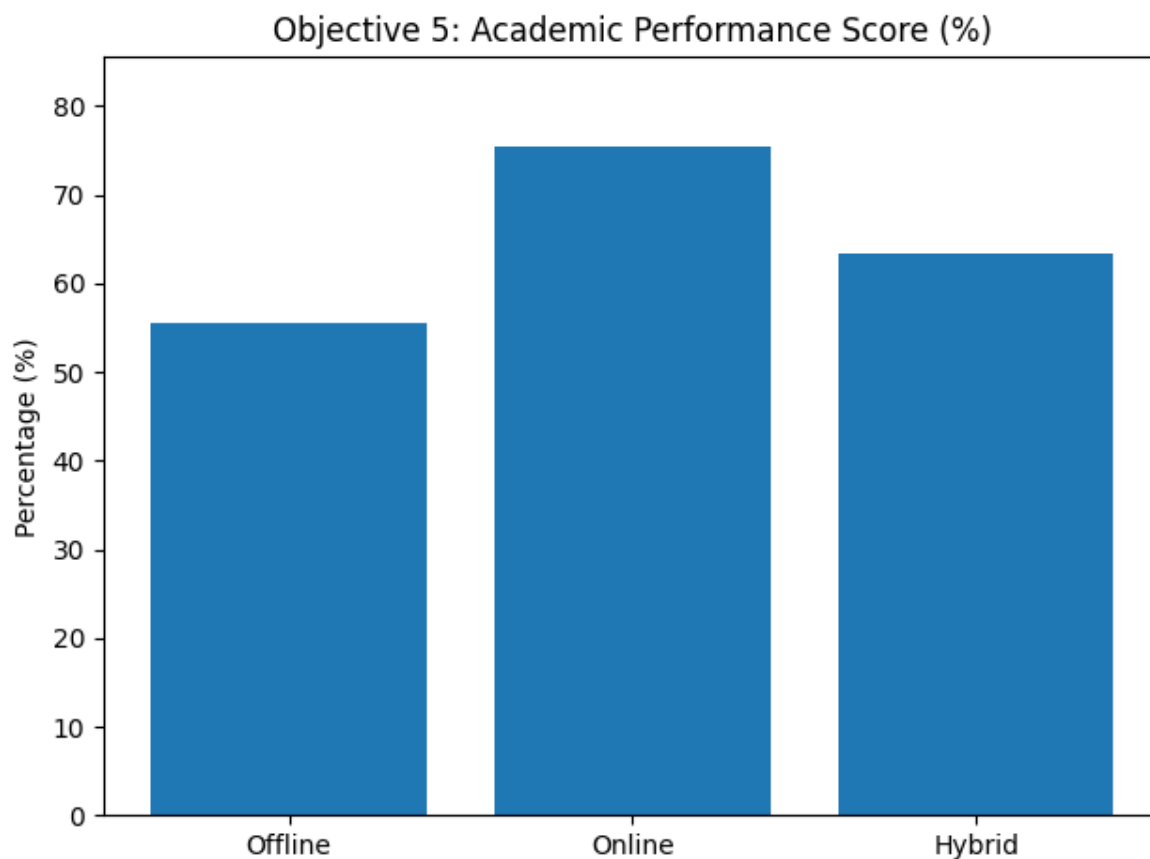
Learning Method	Preference (%)
Experiential Learning	80
Collaborative Learning	75
Traditional Lecture	45



Student perception of STEAM education is generally positive, with learners favoring hands-on, inquiry-based, and collaborative methods over traditional lecturing. Active, experiential, and inquiry-based learning modes significantly improve student engagement, creativity, problem-solving, and interest in STEM, fostering a better understanding of complex, interdisciplinary concepts.

Objective 5

Mode of Learning	Performance Score (%)
Offline	55.5
Online	75.5
Hybrid	63.33



The academic performance score for the offline classes of 100 students is 55.5%.

The academic performance score for the online classes of 100 students is 75.5%.

The academic performance score for the hybrid mode classes of 100 students is 63.33%

Conclusion

The study reveals that hybrid learning modes tend to yield better academic performance in STEM education, followed closely by offline modes, while online modes demonstrate comparatively lower performance. These differences can be attributed to key factors such as student engagement, accessibility to learning resources, and the overall quality of instruction.

Hybrid learning effectively combines the advantages of both online and offline approaches, offering flexibility along with direct interaction, which enhances learning outcomes. Offline learning supports structured environments and hands-on experiences, contributing to relatively strong performance. In contrast, online learning, although flexible and resource-rich, may face limitations in maintaining consistent engagement and practical exposure.

Summary

Mode Academic Performance

Hybrid	High
Offline	Medium-High
Online	Medium-Low

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