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RESEARCH ARTICLE

EXPLORING THE IMPACT OF USING INTELLIGENT TUTORING SYSTEMS (ITS) FOR BIOLOGY LEARNING ON HIGHER SECONDARY STUDENTS' LEARNING MOTIVATION AND ACADEMIC ACHIEVEMENT IN BIOLOGY

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Abstract

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In the evolving landscape of digital education, Intelligent Tutoring Systems (ITS) have emerged as a powerful innovation that harnesses artificial intelligence to deliver personalized, adaptive instruction. These systems emulate human tutors by offering real-time feedback, diagnostic support, and individualized learning pathways-features that are particularly beneficial in science education. Science subjects, such as Biology, often involve complex, abstract concepts and require deep understanding and application-based learning, which traditional teaching methods may not fully support for all learners. The integration of ITS inBiology education presents a promising avenue for enhancing conceptual clarity, sustaining learner engagement, and promoting self-regulated learning.Learning motivation, defined as the internal desire and drive to engage meaningfully in academic tasks, is a key determinant of student success in science. Motivated learners are more likely to persist through academic challenges, actively explore scientific phenomena, and develop lasting interest in the subject. In the context of Biology-an empirical, content-heavy discipline-maintaining learner motivation is particularly critical for achieving academic outcomes.This study investigates the effect of ITS usage on the learning motivation and academic achievement of higher secondary students in Biology. The sample comprised 257 students from Class XI, affiliated with CBSE and CISCE boards in the southern districts of West Bengal. Standardized tools were developed and administered to assess the usage of ITS, motivation toward Biology, and academic performance in the subject. Data were analyzed using descriptive and inferential statistics, including correlation and t-tests.The findings revealed a positive and statistically significant relationship between ITS usage and both learning motivation and academic achievement in Biology. Students who regularly engaged with ITS showed greater interest in Biology, improved problem-solving skills, and higher achievement scores. Differences across gender and board affiliation were also examined, offering nuanced insights into learner diversity and technological impact. These results highlight the potential of ITS to transform Biology education at the secondary level by fostering personalized learning environments that support both cognitive and affective aspects of learning. The study suggests integrating intelligent digital tools into mainstream pedagogy to enhance science learning outcomes and promote equitable, future-ready education.

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Introduction: -

In recent years, the integration of technology into educational settings has transformed traditional approaches to teaching and learning. Among the most innovative developments in this domain is the emergence of Intelligent Tutoring Systems (ITS)—computer-based platforms designed to simulate the guidance of a human tutor by adapting instruction to the individual learner's needs, pace, and progress. Rooted in the principles of artificial intelligence, ITS offer interactive, responsive, and personalized learning experiences that go beyond static digital content, aiming to replicate one-on-one tutoring environments at scale.

As Biology is an empirical and information-rich subject, learners often face challenges in mastering complex concepts, retaining large volumes of content, and applying theoretical knowledge to practical contexts. Traditional instruction methods, though valuable, may not always address individual learning differences or sustain motivation across diverse learners. In this regard, ITS have the potential to significantly enhance Biology learning by offering customized feedback, step-by-step guidance, and engaging content delivery tailored to each student's cognitive profile.

The role of learning motivation—defined as the internal drive and interest that compels students to engage with academic tasks—is crucial in science education. A motivated student is more likely to actively explore content, persist through difficulties, and attain higher academic outcomes. Similarly, academic achievement in Biology reflects not just content mastery but also students' ability to apply concepts in practical or evaluative contexts. Tools like ITS may play a pivotal role in fostering both motivation and achievement by creating more student-centred, interactive learning environments.

While much research has focused on the impact of general digital content or online resources on student performance, fewer studies have specifically examined how AI-driven instructional platforms like ITS influence motivation and achievement in subject-specific contexts such as Biology. Existing literature shows promising but varied results regarding the effectiveness of intelligent systems in promoting deeper learning, especially in STEM disciplines. However, evidence specific to higher secondary education in Biology remains limited.

Against this backdrop, the present study seeks to explore the impact of using Intelligent Tutoring Systems for Biology learning on students' learning motivation and academic achievement at the higher secondary level. It aims to contribute to the understanding of how advanced instructional technologies can support personalized education and potentially transform outcomes in science education.

Emergence of the Study:

The rapid advancement of educational technology, particularly artificial intelligence (AI), has reshaped how learning occurs across disciplines. Among the most significant innovations is the use of Intelligent Tutoring Systems (ITS)—AI-driven platforms that emulate the role of a human tutor by providing personalized, adaptive, and real-time instructional support. In the context of Biology education at the higher secondary level, where learners are expected to comprehend complex, abstract, and information-heavy content, ITS hold promise for enhancing both learning motivation and academic achievement. Traditional pedagogical methods often fall short in meeting the diverse needs of students, especially in large classrooms where individualized attention is limited. While digital resources such as simulations, videos, and e-textbooks have become commonplace, the unique adaptive features of ITS—such as tailored feedback, error-specific guidance, and self-paced progression—warrant focused investigation. Despite the increasing use of ITS globally, limited empirical research exists on their subject-specific impact in secondary education, particularly in India. This study, therefore, emerges from the need to understand whether and how intelligent tutoring systems can be effectively leveraged to improve student engagement and academic outcomes in Biology, contributing to a deeper, more learner-centered approach to science education.

Rise of AI in Education:

The integration of Artificial Intelligence in educational technology has led to the development of Intelligent Tutoring Systems (ITS), which offer personalized and adaptive learning experiences.

- **Need for Subject-Specific Research**:

Although ITS have been studied in general education contexts, there is limited research on their application in Biology education at the higher secondary level, particularly focusing on learning motivation and academic achievement.

- **Challenges in Learning Biology**:

Biology is a complex, information-rich subject that often requires support beyond traditional instructional methods. ITS may help address issues related to content overload, motivation, and individualized learning.

- **Role of ITS in Enhancing Engagement**:

ITS provide real-time feedback, adaptive content delivery, and individualized pacing, all of which can potentially increase student engagement, self-regulation, and intrinsic motivation in Biology.

- **Gap in Existing Literature**:

While digital tools like videos and quizzes have been explored for their educational value, fewer studies have assessed the impact of intelligent, AI-driven tutoring systems on specific academic and motivational outcomes.

- **Post-Pandemic Relevance**:

With the rise of hybrid and remote learning models, especially after the COVID-19 pandemic, there is an urgent need to evaluate how ITS can support learning in a technology-reliant educational environment.

- **Focus of the Current Study**:

This study seeks to explore how the use of ITS in Biology affects higher secondary students' learning motivation and academic performance, helping educators understand the pedagogical value of such systems.

Statement of the Problem:

"Exploring the Impact of Using Intelligent Tutoring Systems (ITS) for Biology Learning on Higher Secondary Students' Learning Motivation and Academic Achievement in Biology."

Objectives of the Study: -

The current research aims to examine the impact and interrelatedness of the usage of Intelligent Tutoring Systems (ITS) in the subject of Biology on students' learning motivation in Biology and their academic achievement in the subject. The following research objectives have been framed to expand existing studies related to the integration of ITS inBiology education:

O1: To measure the extent of usage of Intelligent Tutoring Systems (ITS) in Biology by students studying at the Higher Secondary Level in the southern districts of West Bengal.

O2: To study the level of learning motivation in Biology among students studying at the Higher Secondary Level in the southern districts of West Bengal.

O3: To measure the level of academic achievement in Biology of students studying at the Higher Secondary Level in the southern districts of West Bengal.

O4: To compare the levels of ITS usage in Biology, learning motivation in Biology, and academic achievement in Biology between boys and girls studying at the Higher Secondary Level in the southern districts of West Bengal.

O5: To compare the levels of ITS usage in Biology, learning motivation in Biology, and academic achievement in Biology between students affiliated with the CISCE and CBSE Boards at the Higher Secondary Level in the southern districts of West Bengal.

O6: To compare the usage of ITS in Biology among students across gender and Board of Studies (CISCE and CBSE) categories at the Higher Secondary Level in the southern districts of West Bengal.

O7: To compare students' learning motivation in Biology across gender and Board of Studies categories at the Higher Secondary Level in the southern districts of West Bengal.

O8: To compare the academic achievement in Biology of students across gender and Board of Studies categories at the Higher Secondary Level in the southern districts of West Bengal.

O9: To study the relationship between the usage of ITS in Biology and students' learning motivation in Biology at the Higher Secondary Level in the southern districts of West Bengal.

O10: To study the relationship between the usage of ITS in Biology and academic achievement in Biology of students at the Higher Secondary Level in the southern districts of West Bengal.

O11: To study the relationship between students' learning motivation in Biology and their academic achievement in Biology at the Higher Secondary Level in the southern districts of West Bengal.

Hypotheses of Study:

$H_0$1: There is no significant difference in the level of usage of Intelligent Tutoring Systems (ITS) in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

$H_0$2: There is no significant difference in students' learning motivation in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.

$H_0$3: There is no significant difference in academic achievement in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.

$H_0$4: There is no significant difference in the level of usage of Intelligent Tutoring Systems (ITS) in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$5: There is no significant difference in students' learning motivation in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$6: There is no significant difference in academic achievement in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.
$H_0$7: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their usage of Intelligent Tutoring Systems (ITS) in Biology at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$8: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their learning motivation in Biology at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$9: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their academic achievement in Biology at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$10: There is no significant relationship between the usage of Intelligent Tutoring Systems (ITS) in Biology and students' learning motivation in Biology among students studying at the Higher Secondary Level in Kolkata and adjacentdistricts of West Bengal.
$H_0$11: There is no significant relationship between the usage of Intelligent Tutoring Systems (ITS) in Biology and academic achievement in Biology among students studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.
$H_0$12: There is no significant relationship between students' learning motivation in Biology and their academic achievement in Biology among students studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Operational Terms and Definitions:
To ensure clarity and consistency in understanding the key constructs of the present study, the following operational terms and definitions are presented:
i. Intelligent Tutoring System (ITS):
A computer-based learning system that provides personalized instruction and feedback to learners without human intervention. In the context of this study, ITS refers to AI-driven platforms or software specifically designed to assist students in learning Biology through interactive modules, quizzes, simulations, diagnostic feedback, and adaptive learning pathways.
ii. Usage of Intelligent Tutoring Systems (ITS) in Biology:
The extent to which higher secondary students interact with, utilize, or engage in learning Biology content using ITS platforms. This includes the frequency, duration, and type of usage of such intelligent systems for Biology education.
iii. Learning Motivation in Biology:
The internal drive or inclination of students to engage with and persist in learning Biology. It includes components such as interest, self-efficacy, goal orientation, task value, and perceived relevance of Biology, all operationalized through standardized instruments measuring academic motivation in the subject.
iv. Academic Achievement in Biology:
The degree of academic success attained by students in the subject of Biology, typically measured through standardized test scores, internal assessments, or examination results that reflect understanding, application, and retention of biological concepts.
v. Higher Secondary Level:
The educational stage comprising grades 11 and 12 in the Indian education system, typically involving students aged between 16 and 18 years. It serves as the terminal phase of secondary schooling before university or professional education.
vi. Impact:
The measurable influence or outcome resulting from the usage of ITS on students' learning motivation in Biology and their academic achievement in the subject. This may include observed changes in motivation scores, improved academic performance, or shifts in learning behavior.

vii. Student:
An individual formally enrolled in a recognized educational institution at the Higher Secondary Level (Class XI or XII) and participating in Biology as a subject of study. These individuals constitute the primary unit of analysis in this research.
viii. Operationalization:
The process of translating abstract constructs such as "learning motivation" and "achievement" into specific, measurable indicators that can be empirically observed and analyzed. This involves the use of validated tools, questionnaires, or academic records within the scope of this study.
ix. Adaptive Learning:
A feature of ITS where the content, difficulty level, and feedback are adjusted in real-time based on the learner's individual progress, performance, and response patterns. It ensures a personalized learning experience in Biology.
x. Feedback Mechanism:
The system within ITS that provides learners with immediate, specific, and constructive responses to their inputs, which supports knowledge retention and conceptual clarity in Biology.
xi. Self-Regulated Learning (SRL):
A learner's ability to plan, monitor, and assess their own learning process. ITS tools often promote SRL by encouraging students to set goals, track progress, and take ownership of their biology learning.
xii. Engagement with Technology:
The level of cognitive, emotional, and behavioral involvement of students when interacting with ITS platforms. It includes factors like attention, curiosity, and time spent using the ITS tools for Biology learning.
xiii. Interactive Learning Environment:
A digital educational space provided by ITS where learners actively participate in simulations, problem-solving tasks, and assessments, facilitating deeper understanding of Biology concepts.
xiv. Diagnostic Assessment:
An ITS feature that evaluates a student's prior knowledge and learning needs in Biology, often before instruction begins. This guides the ITS in customizing content to match the learner's level.
xv. Gamification in Learning:
The use of game-like elements—such as points, levels, badges, or rewards—within ITS to increase student motivation, participation, and enjoyment in Biology learning tasks.
xvi. Digital Pedagogy:
The practice of teaching and learning using digital tools and strategies. In this context, it refers to how ITS redefines Biology instruction by integrating AI-driven, learner-centered methods.
xvii. Learning Analytics:
Data collected and analyzed by ITS platforms regarding students' interactions, progress, strengths, and weaknesses. These insights help refine the instructional approach and support academic achievement in Biology.
xviii. Technology Acceptance:
The degree to which students are willing to adopt and consistently use ITS platforms. This includes perceptions of usefulness, ease of use, and trust in the system, which can affect learning motivation and outcomes.
These definitions aim to provide a coherent framework for interpreting and analyzing the variables under investigation, ensuring that each construct is consistently understood within the context of intelligent tutoring systems and their role in Biology education.

Delimitations of the Study: -

1. The study will be delimited to the Kolkata and adjacent districts of West Bengal.
2. The study will be delimited in the municipal parts of the Southern Districts of West Bengal.
3. Only Higher Secondary school students of class XI affiliated to CISCE and CBSE will be considered.
4. The content area for the achievement test will be selected from each unit of the class XI Biology curriculum which are common in both the curriculums of CISCE and CBSE boards.

Significance of the Study:
The significance of the study titled "Exploring the Impact of Using Intelligent Tutoring Systems (ITS) for Biology Learning on Higher Secondary Students' Learning Motivation and Academic Achievement in Biology" lies in its potential to offer evidence-based insights into the role of artificial intelligence-driven instructional tools in shaping educational outcomes in biology education at the higher secondary level.

Advancement in Educational Technology:
In the context of rapidly evolving educational technologies, Intelligent Tutoring Systems (ITS) represent a major innovation that personalizes learning by adapting content and pace to individual learner needs. This study aims to assess how ITS integration influences the effectiveness of biology education, thereby contributing to the growing body of knowledge on AI-based learning solutions in science pedagogy.

Motivation Enhancement:
Learning motivation is a crucial driver of student engagement and academic success. By investigating the impact of ITS on students' intrinsic and extrinsic motivation to learn biology, the study can determine whether these systems foster greater interest, sustained effort, and positive attitudes toward the subject. This will help educators understand the motivational benefits of intelligent digital interventions.

Academic Achievement:
Academic performance in biology is a key metric of educational progress, especially at the higher secondary level where students begin to make career-defining academic choices. This study explores the correlation between the use of ITS and student performance in biology, providing insights into how intelligent tutoring tools can be leveraged to improve learning outcomes.

Implications for Teaching Strategies:
The findings of this study can inform teacher training, instructional design, and classroom practices. By understanding how ITS influences student motivation and achievement, educators can make more informed decisions about integrating AI-powered tools into their lesson plans to cater to diverse learning needs more effectively.

Infrastructure and Policy Development:
Results from the study may influence educational infrastructure planning by highlighting the value of incorporating ITS in school digital ecosystems. Administrators and policymakers can use the findings to prioritize the inclusion of intelligent learning platforms in curriculum and infrastructure development strategies.

Future Research Directions: -

This study lays the groundwork for future academic inquiry into specific features of ITS that enhance learning, the comparative effectiveness of various ITS platforms, and their long-term impact on conceptual understanding and skill development in biology. It opens doors to interdisciplinary research linking pedagogy, psychology, and artificial intelligence.

Stakeholder Benefits:

- **Students:** Will understand the benefits of ITS in enhancing their biology learning experience through personalized feedback and adaptive content delivery.
- **Teachers:** Will gain insights into how ITS can support differentiated instruction and complement traditional teaching methods.
- **School Administrators:** Will recognize the relevance of investing in ITS as a viable tool to improve biology teaching outcomes.
- **Curriculum Designers and Educational Boards:** Will be able to evaluate the need for integrating ITS within the standard biology curriculum and develop guidelines for effective implementation.
- **Policy Makers and Planners:** Will be supported with empirical data to inform strategic decisions regarding ICT inclusion and the deployment of AI-powered tools in science education.
- **Researchers:** Will find this study a valuable reference for exploring AI's role in education, especially in biology and other science disciplines.
- **Parents:** Will develop a clearer understanding of how ITS can contribute to their children’s academic success and sustained motivation in learning biology.

In essence, this study holds significant value in bridging the gap between technology and pedagogy, offering strategic insights into how ITS can be meaningfully embedded in biology education to enrich the teaching-learning process and improve student achievement.

Review of Related Literature: -

Indian Literature:

The integration of digital technologies in science education in India has accelerated in recent years, especially with the National Education Policy (NEP) 2020 emphasizing digital pedagogy and personalized learning. However, the focus on **Intelligent Tutoring Systems (ITS)** in Indian biology education is still emerging and lacks significant empirical coverage.

- **Patel (2018)** conducted a quasi-experimental study in Gujarat on the impact of Computer-Assisted Instruction (CAI) in Biology among Class XI students. The findings revealed significant gains in conceptual clarity and retention among the experimental group using multimedia modules. However, the CAI lacked real-time adaptability, a key feature of ITS.
- **Kundu and Bhowmik (2019)** studied the role of online simulations in enhancing engagement and motivation in biology classes across schools in Kolkata. They emphasized that while ICT tools created an active learning environment, they were often generic and not tailored to individual learner profiles, as ITS ideally should be.
- **Bhattacharya and Roy (2020)** explored the impact of AI-based personalized learning systems used experimentally in select CBSE-affiliated schools in Delhi and Kolkata. Their research reported heightened attention spans, increased question-asking behavior, and deeper understanding of biological processes. However, due to infrastructural limitations, these systems were not scaled.
- **Das and Dutta (2021)** examined students' and teachers' perceptions of AI-supported learning platforms during the COVID-19 pandemic in urban and peri-urban West Bengal schools. They found moderate to high acceptability of AI-driven tools but also noted a lack of teacher training in managing adaptive platforms like ITS.
- **Rani and Sinha (2023)** argued for the contextualization of global ITS tools for Indian curriculum standards, especially in the biological sciences. They proposed that integration of vernacular language support and local content relevance could make ITS more effective in diverse Indian classrooms.
- **Chatterjee and Paul (2022)** identified a positive correlation between digital content exposure and biology achievement in urban schools but highlighted that very few institutions used ITS-like tools. Most relied on video lectures and Google Forms for assessment, lacking the adaptive features of ITS.

In sum, Indian literature points to a readiness for ITS adoption in biology classrooms but reveals systemic barriers such as infrastructure, content alignment, and teacher preparedness. Furthermore, the lack of focused empirical studies on ITS-specific impacts on motivation and achievement in biology signifies a critical research gap.

Literature from Abroad

The international research landscape provides a rich repository of findings on the use of Intelligent Tutoring Systems across various subjects, including biology. These systems are especially prevalent in countries like the USA, Germany, South Korea, and Canada, where educational technology integration is more mature.

- VanLehn (2011) performed a comprehensive meta-analysis of ITS impact, concluding that ITS is almost as effective as human tutoring, with students gaining approximately 0.76 standard deviations in learning performance. The study emphasized ITS benefits in content-heavy subjects like science and mathematics.
- Graesser et al. (2012) developed AutoTutor, an ITS using natural language processing that teaches through interactive dialogues. AutoTutor significantly improved students' ability to grasp biology concepts like DNA replication and cellular respiration compared to conventional computer-based instruction.
- Koedinger et al. (2015) demonstrated the success of ITS in the Cognitive Tutor project, which supported learners in complex subjects by tailoring learning paths. Students showed improved academic outcomes in biology when ITS modules included problem-solving tasks and embedded assessments.
- Roll et al. (2014) explored how ITS fosters self-regulated learning. Their study showed that when students used systems that prompted them to plan, monitor, and evaluate their learning, they demonstrated improved biology performance and were more motivated to study independently.
- Hwang et al. (2020) designed an Augmented Reality-based ITS for high school biology in Taiwan. Their findings revealed that students not only performed better in lab tasks but also showed higher interest in pursuing biology in higher education.
- Rus et al. (2019) examined ITS systems for diverse populations, underscoring the importance of culturally responsive design. They found that systems integrating local examples and language-specific scaffolding were more successful in maintaining learner engagement.

- Chou et al. (2021) studied ITS usage in a flipped biology classroom and found that students using ITS were better able to apply biological concepts in novel situations, suggesting higher-order cognitive development.

These international studies strongly support the efficacy of ITS in improving student achievement, motivation, and self-regulation in biology. They also underscore the value of dynamic feedback, learner analytics, and dialogic interactivity, which are hallmarks of effective ITS.

Literature Related to Operational Terms:

a. Intelligent Tutoring Systems (ITS)

ITS are AI-powered educational systems designed to deliver individualized instruction.

- **Woolf (2009)** characterized ITS as four-module systems consisting of a domain model, student model, tutoring model, and user interface.
- **Aleven et al. (2016)** described ITS as systems capable of "cognitive tutoring," which mirrors human-like responsiveness to student inputs.
- **Nkambou et al. (2010)** outlined ITS development stages and stressed their relevance for high-cognitive-load subjects like biology.
- **Roll & Wylie (2016)** observed that ITS improved not only content mastery but also learning behavior, such as time management and error monitoring.

b. Usage of ITS in Biology

ITS applications in biology are less frequent but increasing due to the subject's conceptual complexity.

- **Samarasinghe et al. (2018)** developed BioLearn, an ITS for cellular biology, which significantly improved students' retention and application skills.
- **Hwang et al. (2020)** introduced AR-assisted ITS for biology practicals and noted greater lab accuracy and concept retention.
- **Blanchard et al. (2016)** studied ITS integration in AP Biology courses and found positive effects on inquiry skills and data interpretation.
- **Guo et al. (2021)** highlighted the advantage of ITS in simulating biological processes such as mitosis or osmosis, offering visual and interactive representation not possible in traditional formats.

c. Learning Motivation in Biology

Motivation is central to learning science effectively.

- **Deci & Ryan (1985)** proposed Self-Determination Theory (SDT), emphasizing intrinsic and extrinsic motivation shaped by autonomy, competence, and relatedness.
- **Glynn et al. (2011)** constructed the Science Motivation Questionnaire II (SMQ-II), validated across global contexts to assess science motivation.
- **Osborne et al. (2003)** highlighted that motivation in biology is influenced by personal relevance, teacher approach, and hands-on engagement.
- **Sarkar and Choudhury (2019)** found that Indian students' biology motivation increased when real-life examples and multimedia were used.
- **Kundu (2020)** demonstrated that students using digital concept maps in biology showed greater interest and self-driven learning behavior.

d. Self-Regulated Learning (SRL)

SRL includes metacognition, motivation, and behavior regulation strategies.

- **Zimmerman (2002)** emphasized the cyclic model of SRL: forethought, performance, and self-reflection.
- **Winne & Nesbit (2010)** showed ITS platforms could facilitate SRL by providing reflective feedback and encouraging planning strategies.
- **Paris and Paris (2001)** linked SRL with deeper learning in biology due to complex and interconnected topics.
- **Dabbagh and Kitsantas (2012)** advocated for ITS as SRL-enhancing tools through prompts, goal setting, and real-time monitoring.

e. Academic Achievement in Biology

Achievement in biology is often linked to effective teaching strategies and learning aids.

- **Yusuf and Afolabi (2010)** showed multimedia teaching led to higher scores in biology achievement tests.

- **Tamir (1994)** categorized biology achievement factors into cognitive (knowledge), affective (interest), and psychomotor (lab skills).
- **Mishra and Nath (2021)** found that use of interactive simulations in Indian schools led to significant improvement in higher-order biology tasks.
- **Sharma and Pal (2022)** identified conceptual clarity and problem-solving as key academic outcomes influenced by ITS tools.

f. Digital Pedagogy

Digital pedagogy integrates ICT tools to improve curriculum delivery.

- **Beetham & Sharpe (2013)** defined digital pedagogy as the intelligent application of digital tools to develop new learning experiences.
- **Mishra and Koehler (2006)** proposed the TPACK model, underlining the intersection of technological, pedagogical, and content knowledge.
- **Chakraborty (2021)** studied Indian secondary schools and found digital pedagogy in biology increased students' conceptual understanding and recall.
- **Kirkwood & Price (2014)** cautioned that technology use alone does not improve outcomes unless guided by sound pedagogy.

Literature Significant for Tool Development:

a. Measuring Extent of Usage of ITS

Few standardized instruments exist to measure ITS usage, especially in specific disciplines.

- **Aleven et al. (2016)** used system log data and learner feedback to evaluate frequency, duration, and depth of ITS use.
- **Zhou & Wang (2020)** developed a Likert-based ITS Perception Scale to measure attitudes, engagement, and usability in secondary education.
- **Singh & Thakur (2023)** proposed a Digital Tutoring Usage Index (DTUI) for Indian classrooms, though it lacked biology-specific dimensions.
- **Cheung et al. (2022)** recommended multi-method assessment including observational rubrics, self-report, and digital trace data.

b. Measuring Learning Motivation in Biology

Instruments for assessing science motivation are abundant and adaptable.

- **Glynn et al. (2011)** developed the **SMQ-II**, which has subscales for intrinsic motivation, self-efficacy, grade motivation, career motivation, and learning environment.
- **Roy and Chatterjee (2020)** adapted the SMQ-II for Indian Class XI biology students, ensuring alignment with local curricular and cultural contexts.
- **Kebritchi et al. (2010)** suggested using mixed-method tools to evaluate motivation changes due to digital learning environments.

A Literature review matrix which is presented below will summarize the major findings found by the present researcher through review of Literature.

Table 2.1.: - A Literature review matrix about major findings found by the present researcher through review of literature.

Researcher(s)	Year	Place	Design	Independent Variable(s)	Dependent Variable(s)	Key Findings
Sharma & Sharma	2018	India	Quantitative	Digital learning resources	Attitude towards Biology	Digital use improved student attitudes.
Bhattacharya	2017	India	Qualitative	Digital technology integration	Engagement	High tech integration increased engagement.
Singh	2019	India	Mixed Methods	Role of digital media	Biology learning experience	Enhanced learning with digital media.

Bhalerao & Khot	2016	India	Correlational	Attitude towards Biology	Achievement in Biology	Positive correlation between attitude and achievement.
Patil & Patil	2018	India	Experimental	Digital learning materials	Learning outcomes in Biology	Digital content improved outcomes.
Gupta & Reddy	2020	India	Quantitative	Digital content usage	Learning outcomes, Attitude	Higher usage linked with better outcomes and attitudes.
Cheung & Slavin	2013	International	Meta-Analysis	Digital learning content	Student learning outcomes	Significant positive effects of digital learning across subjects.
Higgins, Beauchamp & Miller	2007	International	Mixed Methods	Interactive whiteboards	Secondary learning outcomes	Improved active learning and outcomes.
Tarng & Tsai	2012	Taiwan	Quantitative	Digital educational resources	Motivation for learning Science	Interactive content boosted motivation.
Lin & Hwang	2010	Taiwan	Experimental	Multimedia instruction	Attitudes, Learning outcomes	Multimedia enhanced both attitude and achievement.
Schmid et al.	2014	International	Meta-Analysis	Digital technologies	Teaching and learning effectiveness	Advanced tech integration improved effectiveness.
VanLehn	2011	USA	Meta-Analysis	Intelligent Tutoring Systems (ITS)	Student learning outcomes	ITS nearly as effective as human tutoring.
Graesser et al.	2012	USA	Experimental	AutoTutor ITS	Biology concept mastery	Dialogic ITS enhanced concept understanding.
Roll et al.	2014	USA	Experimental	ITS prompting SRL	Achievement, SRL	ITS encouraged self-regulation and performance.
Hwang et al.	2020	Taiwan	Experimental	AR-based ITS	Biology performance, Interest	Improved lab skills and future interest in biology.
Rus et al.	2019	International	Comparative Study	Cultural responsiveness in ITS	Engagement	Localized ITS improved student engagement.
Chou et al.	2021	Taiwan	Experimental	ITS in flipped classroom	Concept application	Promoted higher-order thinking in Biology.

Critical Appraisal of Reviewed Literature

The body of literature reviewed—both national and international—reflects a growing interest in leveraging digital tools for improving educational outcomes, particularly in science disciplines like Biology. Studies consistently indicate that digital content and instructional technologies contribute positively to students' motivation, engagement, and academic achievement. However, a critical appraisal of the literature also reveals several limitations and significant gaps that underline the necessity of the present study.

Strengths of the Existing Literature

1. **Diverse Methodologies:** A wide array of methodological approaches—quantitative, qualitative, experimental, and meta-analytic—have been employed to explore digital learning. This methodological diversity enriches the evidence base, supporting the positive effects of digital tools on learning motivation and achievement.
2. **Global Emphasis on ITS:** International studies (e.g., VanLehn, Graesser, Roll, Hwang) provide compelling empirical support for the use of Intelligent Tutoring Systems (ITS) in science education. These systems have been shown to deliver adaptive feedback, foster self-regulated learning, and improve conceptual understanding in Biology.
3. **Technology-Motivation Link:** Multiple studies across contexts affirm a strong link between technology usage and student motivation. The use of multimedia, interactive whiteboards, and AR-based systems has consistently shown motivational benefits.
4. **Correlation Between Attitude and Achievement:** Both Indian and global research confirm a positive correlation between students' attitudes towards science subjects and their academic performance, supporting the dual focus of the present study.

Limitations of the Existing Literature

1. **Limited Indian Research on ITS:** While India has seen increasing research on digital learning, most studies focus on general multimedia or internet-based tools. Very few studies directly investigate the use of **Intelligent Tutoring Systems**, particularly in Biology education. This reflects a critical gap in localized evidence.
2. **Lack of Contextual Adaptation:** Much of the international ITS research is situated in highly resourced settings, often without attention to the contextual challenges of infrastructure, curriculum alignment, or teacher readiness in developing countries like India.
3. **Insufficient Operational Measurement Tools:** There is a dearth of standardized and validated tools in Indian studies to measure the **extent of ITS usage**, **motivation levels specific to Biology**, or **self-regulated learning behaviors**, particularly at the higher secondary level. Many existing tools are general and not discipline-specific.
4. **Limited Focus on Higher Secondary Level:** Most studies focus on either elementary or undergraduate learners. The higher secondary stage—where career shaping decisions are often made—is underrepresented in the literature, despite its significance in science education pathways.
5. **Gender and Board-Level Disaggregation Rarely Addressed:** While your study includes analysis across gender and education boards (CISCE and CBSE), few previous works have compared how these variables interact with ITS usage, motivation, and achievement in Biology.

Summary of the Review

The review of related literature reveals the increasing relevance and effectiveness of Intelligent Tutoring Systems (ITS) in enhancing academic outcomes and learner motivation in science education, particularly in biology.

From the Indian context, while digital education has seen steady growth, ITS implementation remains minimal. Studies show positive outcomes from digital platforms and multimedia instruction in biology, but they largely lack adaptiveness and real-time feedback. There is also a significant gap in ITS-related research, particularly at the higher secondary level, and an absence of standardized tools for evaluating ITS usage and motivational outcomes. Infrastructural limitations, lack of teacher training, and insufficient localization of ITS content further hinder its mainstream adoption.

From the international perspective, ITS has proven to be a highly effective tool in boosting academic performance and learner engagement. Features such as personalized feedback, dialogue-based learning, and scaffolding strategies cater to individual learning styles and needs. ITS platforms like AutoTutor, Cognitive Tutor, and AR-based intelligent tutors have shown significant improvements in motivation, concept mastery, and self-regulated learning among biology learners. Moreover, these systems are being increasingly tailored for cultural and curriculum relevance, indicating their scalability across educational contexts.

In relation to the operational terms, strong empirical and theoretical foundations exist for concepts such as learning motivation, self-regulated learning, academic achievement in biology, and digital pedagogy. Notable frameworks like Self-Determination Theory (Deci & Ryan), Zimmerman's SRL Model, and the TPACK model provide useful lenses for interpreting how ITS interacts with learner psychology and performance. However, literature emphasizes the importance of contextualizing these models for effective implementation in diverse settings like Indian secondary schools.

Finally, regarding tool development, validated instruments exist globally to measure ITS usage and science motivation, including the SMQ-II and ITS usage scales based on log data and learner feedback. However, India-specific, biology-aligned adaptations of these tools are scarce and essential for meaningful data collection in local contexts.

Research Gap and Justification

Despite strong evidence for the educational potential of digital tools, there exists a conspicuous lack of:

- Empirical studies on ITS usage in Indian Biology education,
- Context-sensitive research at the higher secondary level, and
- Reliable, validated tools for measuring ITS usage and learning motivation in this context.

The present study addresses these critical gaps by focusing on higher secondary students in Southern West Bengal, exploring how the consumption of ITS-related digital content influences both motivation and achievement in Biology, and assessing this across gender and board affiliations. Furthermore, it contributes to tool development and validation specific to ITS usage and Biology motivation at this level.

Justification of the Current Study

The present study is justified on multiple grounds. It explores a relatively under-researched intersection of Intelligent Tutoring Systems (ITS), Biology education, and higher secondary learners within the Indian context. Focusing specifically on Class XI students, the study addresses a crucial academic stage where subject motivation and performance shape future educational and career choices. By concentrating on the Southern districts of West Bengal, the research gains contextual relevance, reflecting local socio-educational realities. Furthermore, the study undertakes the development and validation of new tools specifically designed to assess the extent of ITS usage and learning motivation in Biology, making it both methodologically robust and pedagogically relevant. Lastly, by examining demographic variables such as gender and board affiliation, the study adopts an inclusive approach that allows for a nuanced understanding of how ITS impacts diverse learner groups.

Conclusion: -

This review clearly underscores the need and scope for a study focusing on the impact of Intelligent Tutoring Systems in Biology education among Indian higher secondary students. The existing research points to ITS as a promising intervention capable of fostering personalized learning, enhancing motivation, and improving achievement, especially when grounded in culturally relevant pedagogy and supported by robust assessment tools. The present study, therefore, stands to fill a critical research gap and contribute to both theoretical understanding and practical strategies for educational innovation in Indian science education.

Methodology:-

Research Methodology:-

A quantitative research methodology was tailored for the study to measure theextent of Usage of Intelligent Tutoring Systems (ITS) for Biology on developing the Learning Motivation towards biology and achievement in biology at the higher secondary level:

Research Design:

Quantitative study was performed, which will be a survey that is descriptive in nature. Tools like questionnaire, achievement scale, aptitude scales were developed to collect data.

Variables:

Major Variable:

a)Usage of Intelligent Tutoring Systems (ITS) for Biology (Independent Variable)
b)Learning Motivation towards Biology (Dependent Variable)
c)Achievement in biology (Dependent Variable)

Demographic/ Categorical Variables:
a.Gender of the Student (Girl and Boy)
b.Board of Study (CBSE and CISCE)

Research Tool:
Tools of the Study:
i.Usage of Intelligent Tutoring Systems (ITS) for Biology: A tool with 5-point rating scale, named UITSB (Usage of Intelligent Tutoring Systems (ITS) for Biology) was developed by the researcher for the study (Appendix - I).
ii.Learning Motivation towards Biology: A self-made tool with 5-point rating scale, LMTB (Learning Motivation Towards Biology) was developed to measure the attitude of students for the study (Appendix - II).
iii.Achievement in biology: A survey will be done to the respective shortlisted CBSE and CISCE board schools to get the Biology Achievement Test scores of the students in the Annual Examinations of the respective schools and from that Z-scores will be calculated as this will convert data values into a standard normal distribution.
iv.Data Analysis: 29th version of the software SPSS (Statistical Packages for Social Sciences) will be used for analysing the data related to the study.
•Both the tools (scales) namely UITSB and LMTB were constructed by the present researcher with the help of the Professors and Experts in the field. Initially total items were 35 which were brought down to 32 after expert validation. The categories of responses were Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree and 5, 4, 3, 2, 1 were the respective scores to be awarded for the responses. Some items are negative in nature and the scoring to be done in reverse order in those case like 1, 2, 3, 4, 5.

Reliability of Tools:
- **LMTB Scale** (32 items): Cronbach's Alpha = **0.953** (High reliability)
- **UITSB Questionnaire** (32 items): Cronbach's Alpha = **0.931** (Decent reliability)

Data Collection Procedure:
The researcher personally collected the data by physically visiting the schools and administering the two tools of the study.
To determine the Achievement score, the researcher appealed to the respective schools to provide with the Annual Examination Scores of the students in Biology, and then that data were analysed by virtue of calculating the Z-scores of the same as Z-scores convert data values into a standard normal distribution.

Sampling Method:
Stratified Random Sampling:
Stratified Random sampling method was followed for selecting the samples from the population.

Data Analysis:
Statistical Techniques:
Appropriate statistical techniques were employed to examine relationships between variables and to test the hypotheses. Descriptive statistics were used to summarize the data. Pearson's correlation analysis was applied to assess relationships between digital content consumption and attitude or achievement in biology.
Student's t-test was conducted to compare mean scores across gender and board affiliations. For comparisons among more than two groups, Analysis of Variance (ANOVA) was used. When significant differences were found through ANOVA, post hoc tests were performed. All analyses were conducted at the 0.05 level of significance.

Research Sample:
Population: Students studying at Higher Secondary Level in the southern districts of West Bengal belonging to the CISCE and CBSE Boards.

Sample Size:
A pool of 257 students were selected from various schools of Kolkata and adjacent disctrictsof Kolkata, West Bengal.

Table 3.1.:-Gender of Student wise Sample.

Gender of Students wise Sample					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Girl	99	38.52%	38.52%	38.52%
	Boy	158	61.48%	61.48%	100.0
	Total	257	100.0%	100.0%	

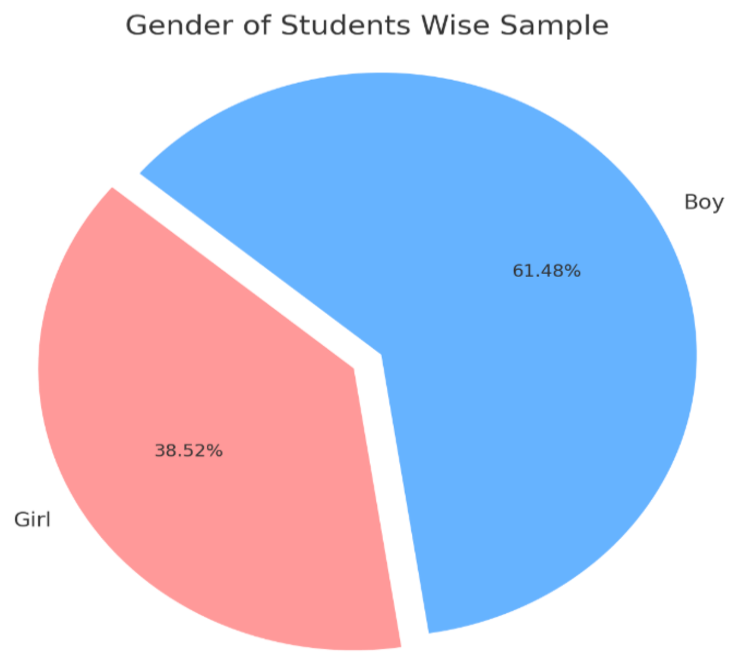

Fig. 3.1:- Gender of Student wise Sample.

Table 3.2.:-Board of Study of the Student wise Sample.

School Board of Students wise Sample					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	**CBSE**	124	48.25%	48.25%	48.25%
	CISCE	133	51.75%	51.75%	100.0%
	Total	257	100.0%	100.0%	

Table 3.3.:-Strata wise Sample.

Gender Strata wise Sample					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	**Girl CBSE**	53	20.62%	20.62%	20.62%
	Girl CISCE	46	17.90%	17.90%	38.52%
	Boy CBSE	71	27.63%	27.63%	66.15%
	Boy CISCE	87	33.85%	33.85%	100.0%
	Total	257	100.0%	100.0%	

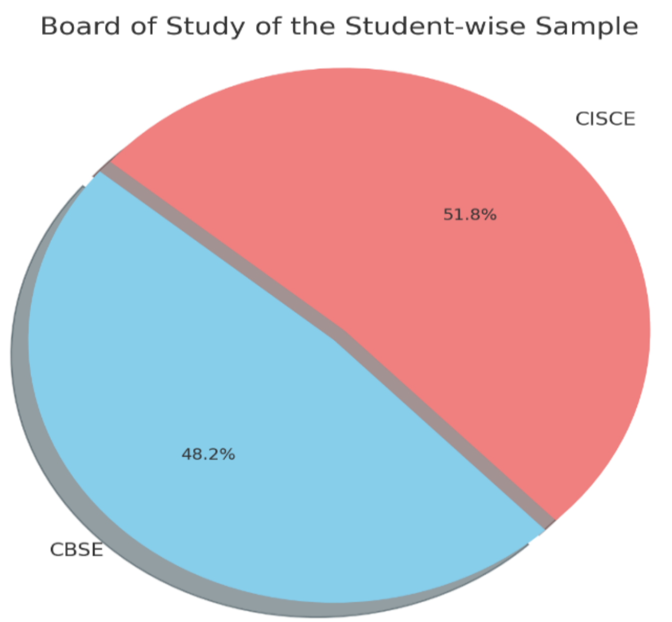

Fig. 3.2:- Board of Study of Student wise Sample.

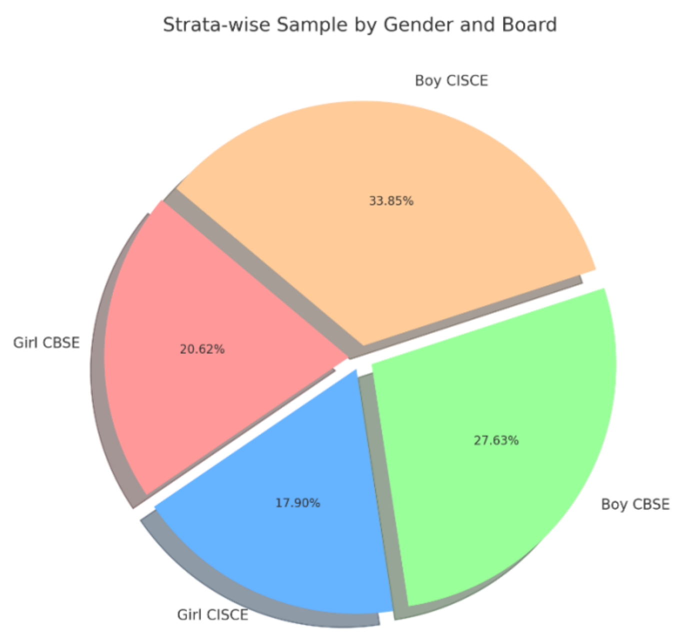

Fig. 3.3:- Gender-Strata wise Sample.

Presentation of Data:
All the raw data were tabulated in MS Excel version 2021 and further analyses were done in IBM SPSS 29.0 version by importing data from excel file.

• IBM SPSS 29.0 Version:
IBM SPSS Version 29.0 is a comprehensive statistical software suite widely used for data analysis, management, and reporting across various fields, including education, business, healthcare, and social sciences. It offers robust tools for handling large datasets, transforming data, and performing both basic and advanced statistical analyses.

Key features include descriptive statistics, t-tests, ANOVA, regression, non-parametric tests, and advanced options like factor and cluster analysis.

Descriptive Statistics:
Learning Motivation Towards Biology **(LMTB)**
Table 3.4: -Descriptive Statistics of Learning Motivation Towards Biology (LMTB).

Statistic	**Value**
N (Valid Cases)	257
Mean	118.74
Standard Deviation	17.89
Median	119.00
Minimum	73
Maximum	160
Range	87
Skewness	-0.407
Kurtosis	-0.534
95% Confidence Interval (CI)	[116.55, 120.94]

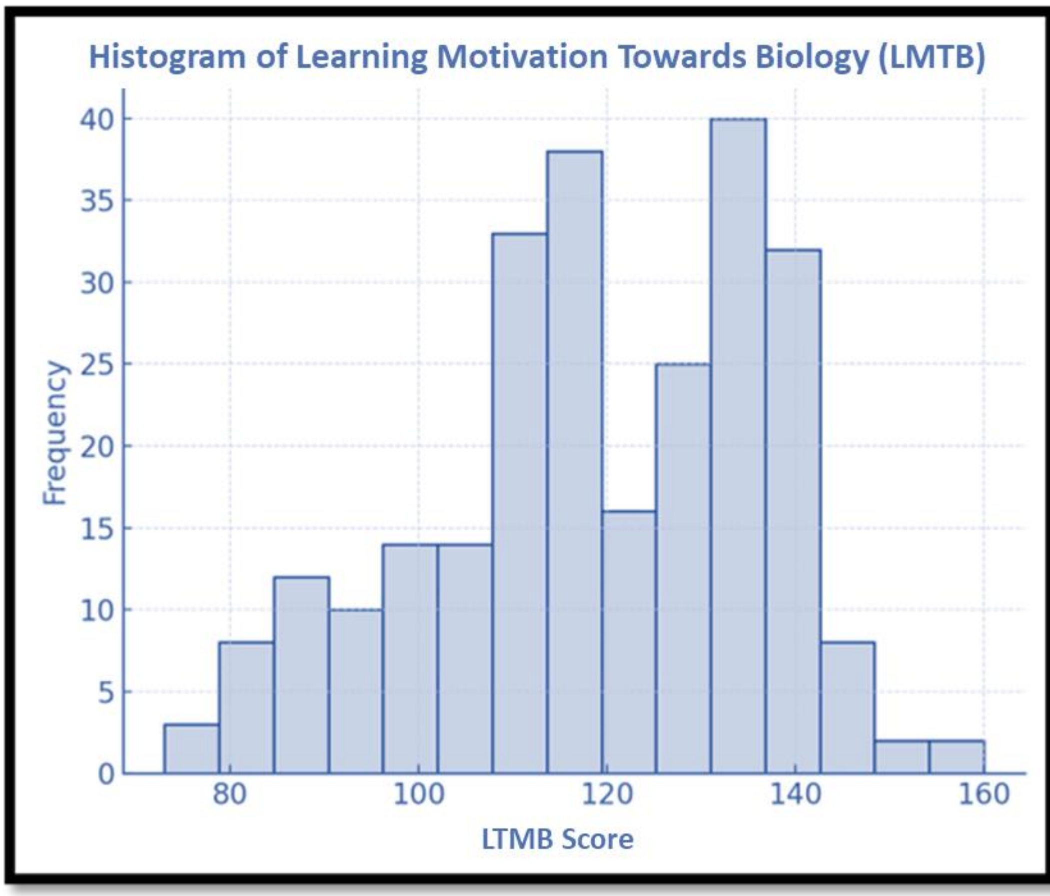

Fig. 3.4:- Histogram _ LMTB.

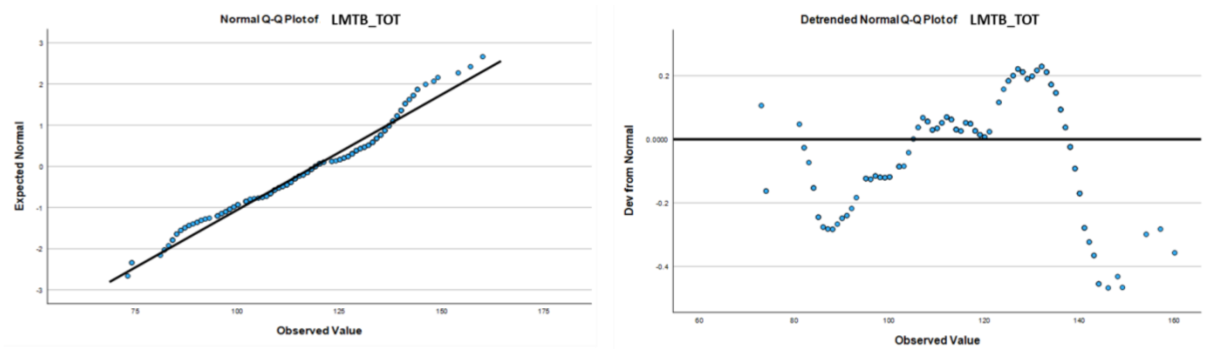

Fig. 3.5:- Normal and Detrended Normal Q-Q Plot for LMTB_TOT.

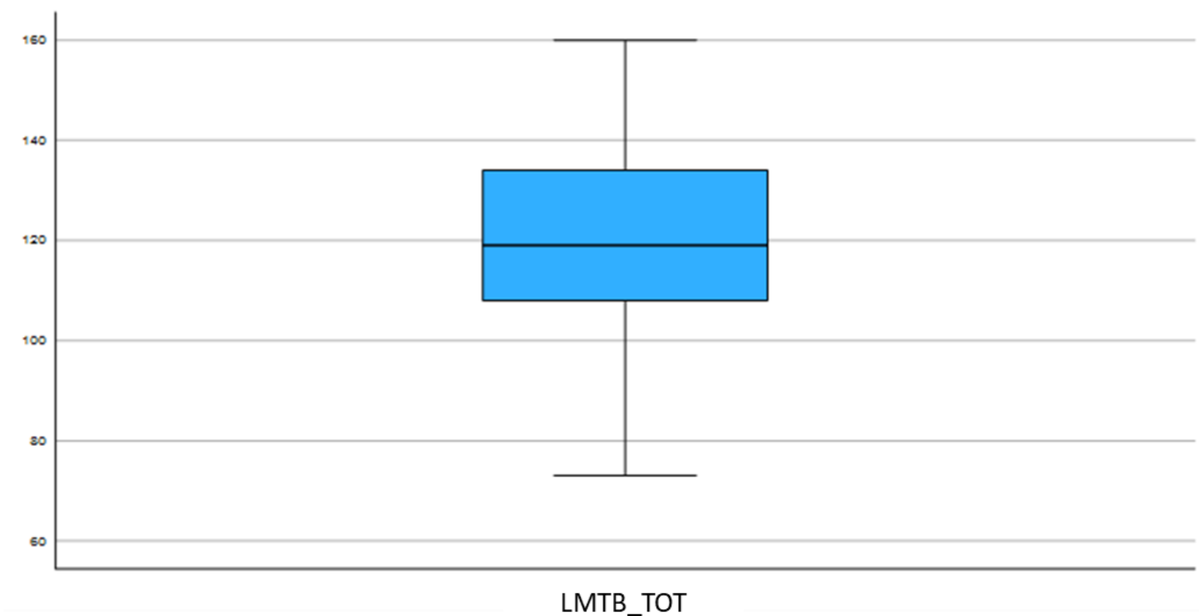

Fig. 3.6:- Box Plot LMTB_TOT.

Interpretation:
The learning motivation scores are fairly symmetrically distributed (skewness ≈ 0) and show moderate variability. The average score of 118.74 indicates a **moderately positive learning motivation** among higher secondary students toward Biology.

Group Statistics of Learning Motivation Towards Biology (LMTB)
By Gender
Table3.5:-Group Statistics of Learning Motivation Towards Biology (LMTB) _ Gender wise.

Gender	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Boys	158	121.00	16.839	1.340
Girls	99	115.14	18.992	1.909

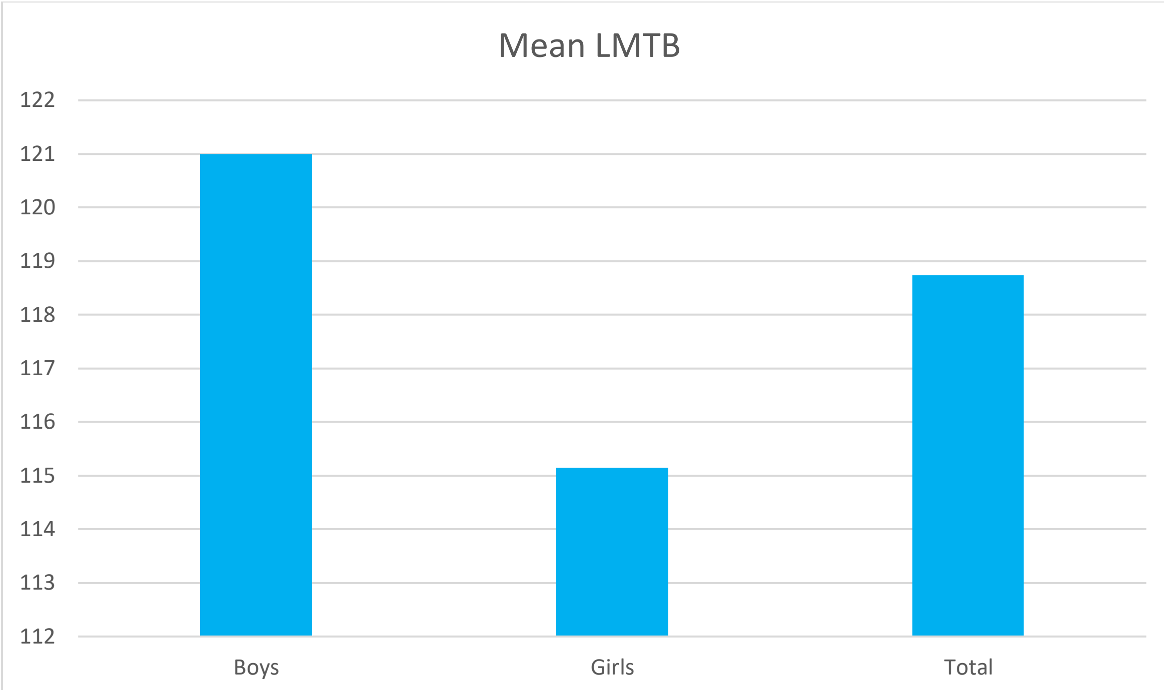

Fig. 3.7:- Group Statistics of LMTB _ Gender Wise.

By Board

Table 3.6:-Group Statistics of Learning Motivation Towards Biology (LMTB) _ Board wise.

Board	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
CBSE	124	125.21	18.760	1.685
CISCE	133	112.71	14.732	1.277

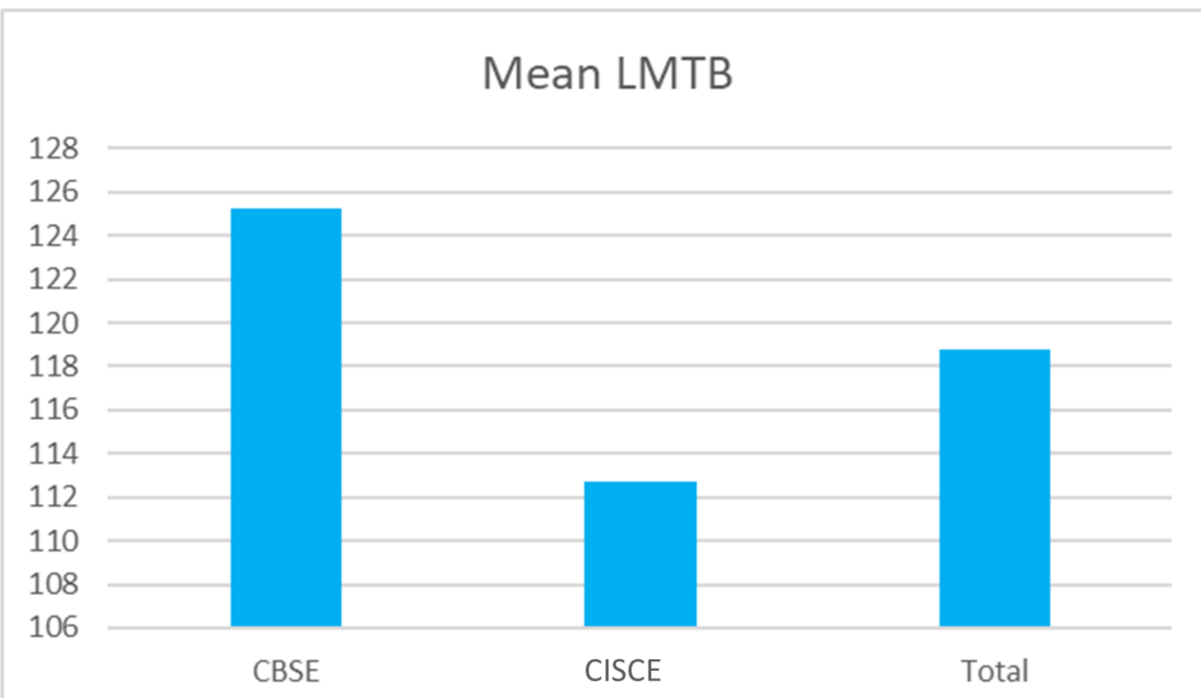

Fig. 3.8:- Group Statistics of LMTB_ Board wise.

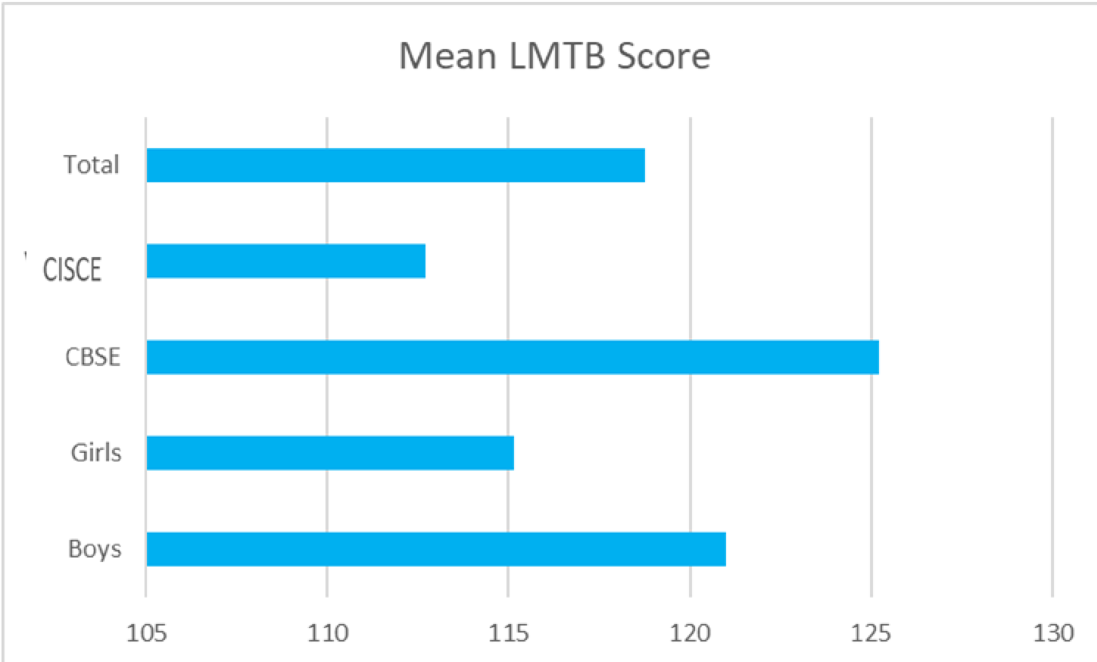

Fig. 3.9: - Overall Mean Score LMTB.

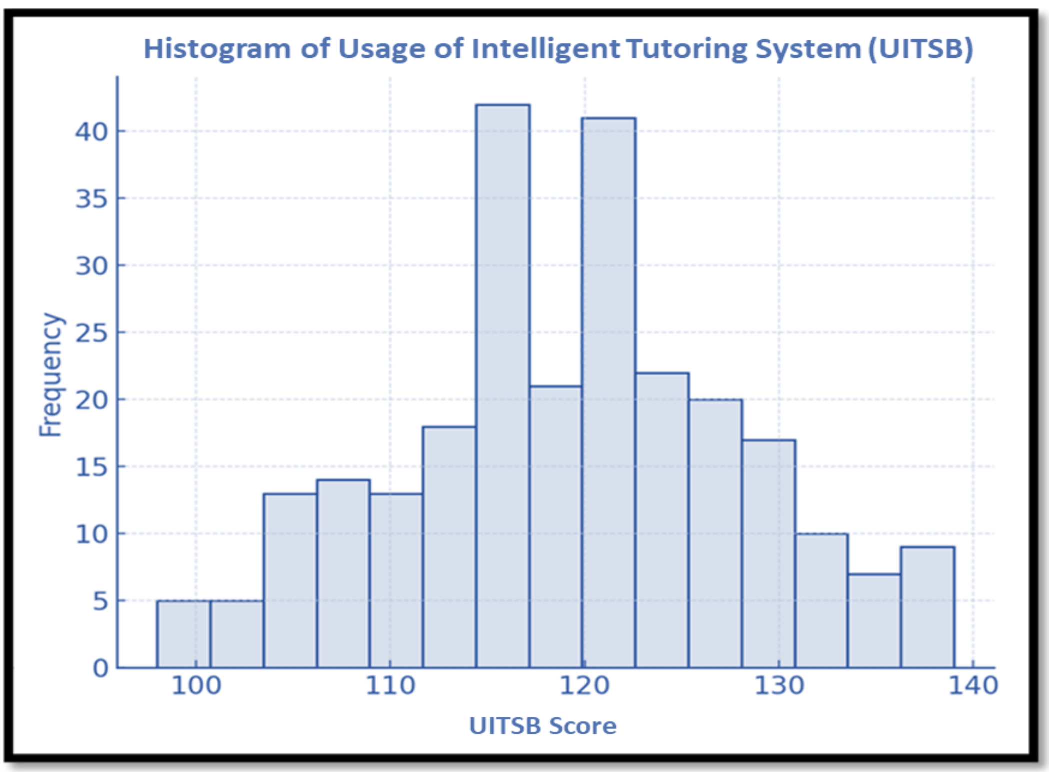

Fig. 3.10:- Histogram _ UITSB.

Descriptive Statistics: Usage of Intelligent Tutoring Systems **(UITSB)**

Table 3.7:-Descriptive Statistics of Usage of Intelligent Tutoring Systems (UITSB).

Statistic	Value
N (Valid Cases)	257
Mean	119.18

Standard Deviation	8.92
Median	119.00
Minimum	98
Maximum	139
Range	41
Skewness	-0.023
Kurtosis	-0.293
95% Confidence Interval (CI)	[118.08, 120.27]

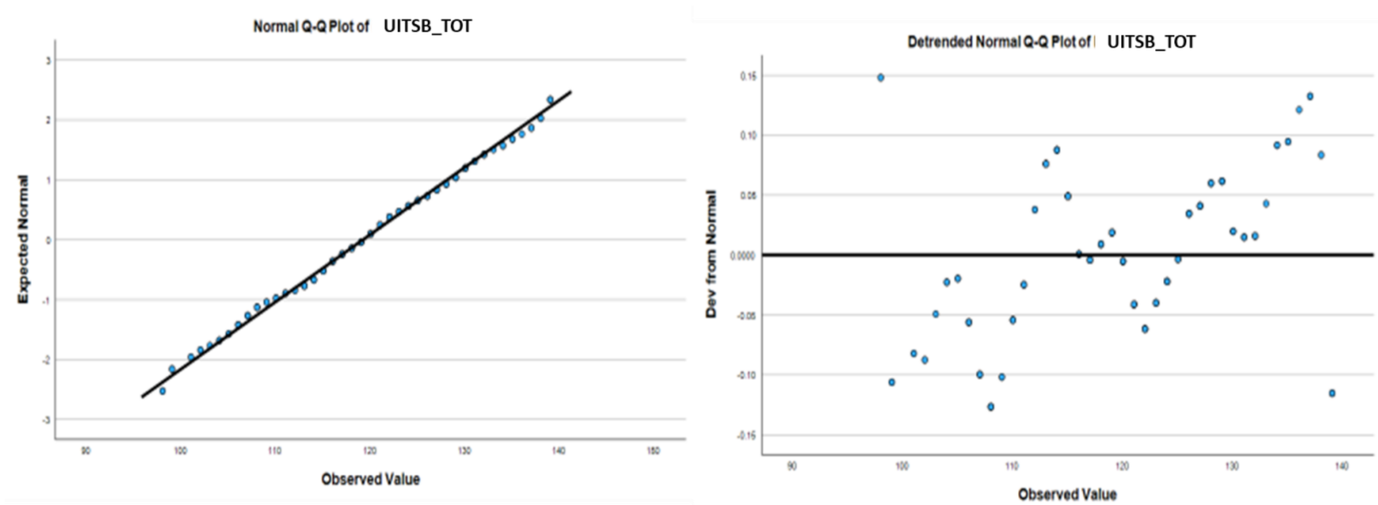

Fig. 3.11:- Normal and Dtrended Normal Q-Q Plot for UITSB_TOT.

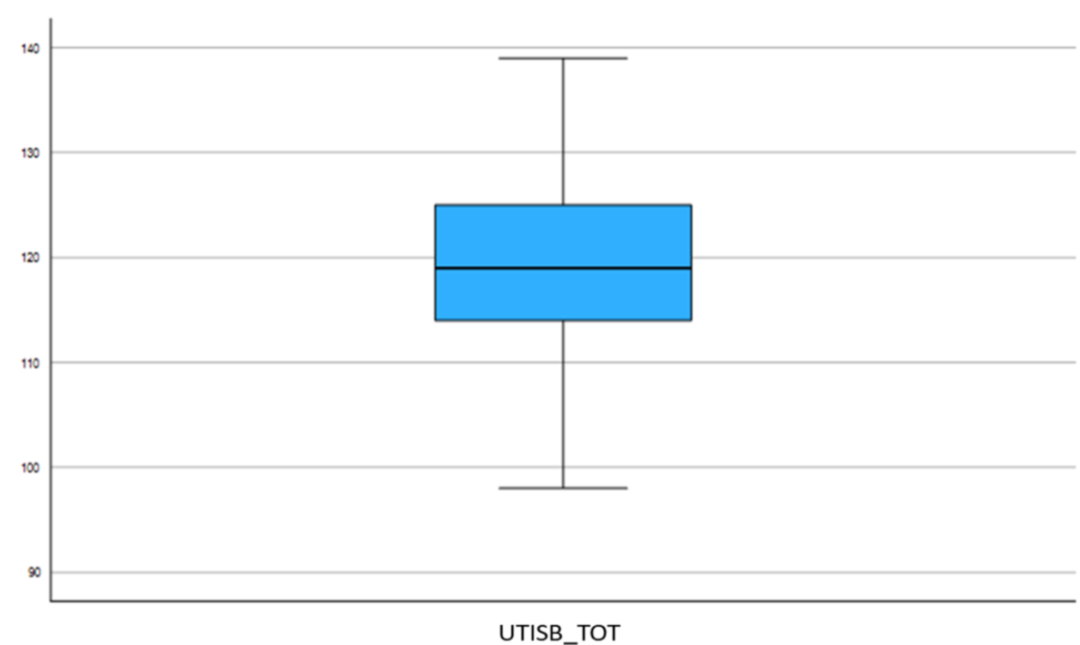

Fig. 3.12: - Box Plot UITSB_TOT.

Interpretation:
The UTISB scores are tightly clustered around the mean and nearly normally distributed (skewness and kurtosis ≈ 0). Students show a uniform and moderately high level ofIntelligent Tutoring Systemsusage.
Group Statistics of Usage of Intelligent Tutoring Systems (UITSB)

By Gender

Table 3.8:-Group Statistics of Usage of Intelligent Tutoring Systems (UITSB) _ Gender wise.

Gender	N	Mean	Std. Deviation	Std. Error Mean
Boys	158	119.22	8.275	0.658
Girls	99	119.12	9.899	0.995

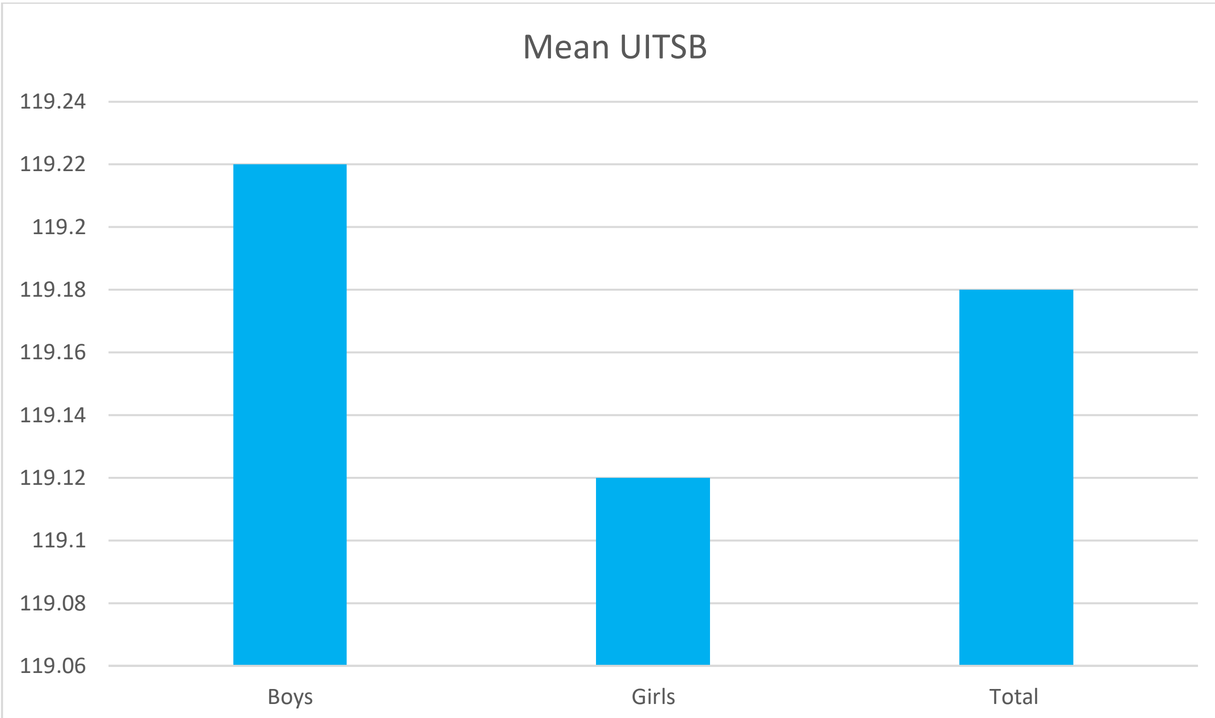

Fig. 3.13: - Group Statistics of UITSB _ Gender wise.

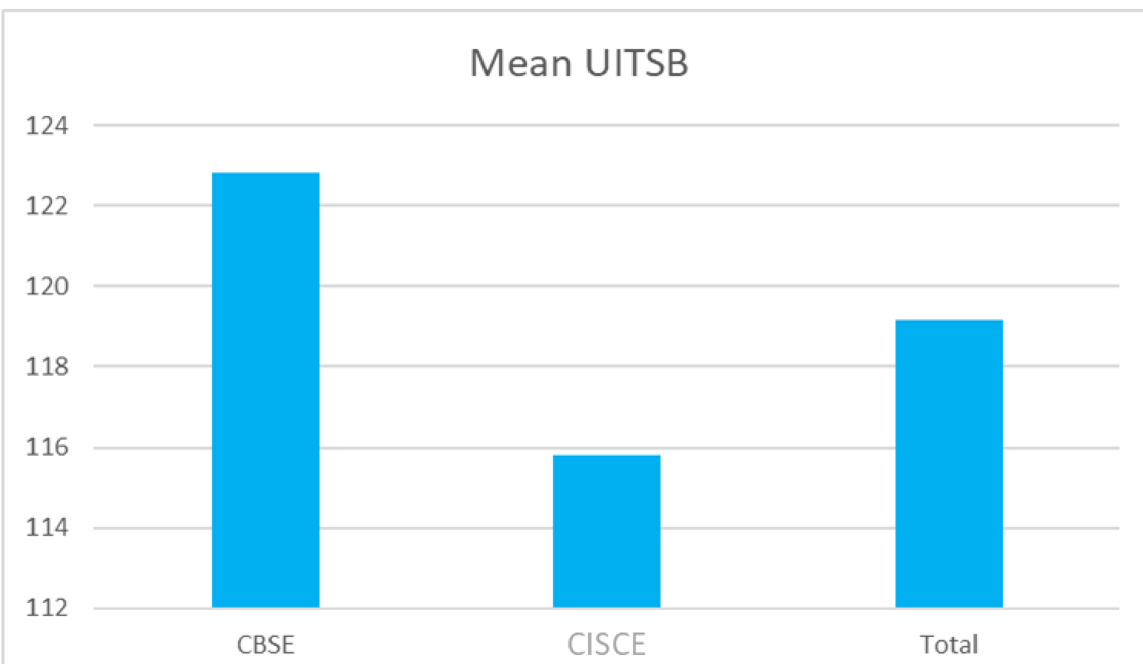

Fig. 3.14: - Group Statistics of UITSB _ Board wise.

By Board

Table 3.9:-Group Statistics of Usage of Intelligent Tutoring Systems (UITSB) _ Board wise.

Board	N	Mean	Std. Deviation	Std. Error Mean
CBSE	124	122.81	10.010	0.899
CISCE	133	115.80	6.080	0.527

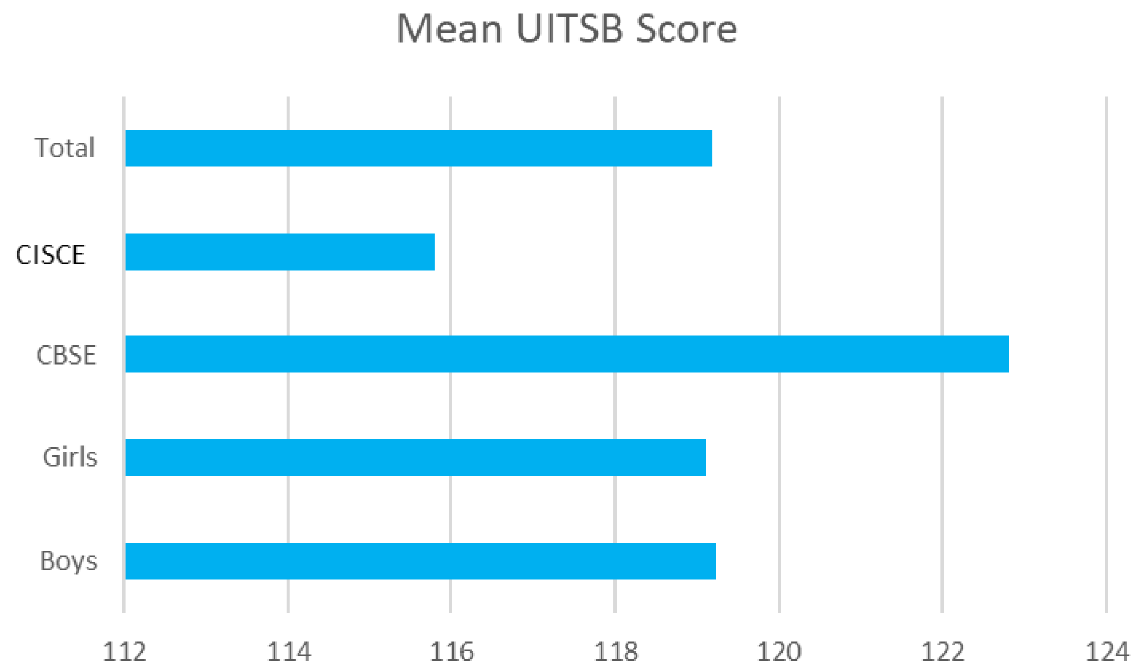

Fig. 3.15: - Overall Mean Score UITSB.

Descriptive Statistics: Achievement in Biology (ACHB)
(Standardized as Z-scores)

Table 3.10:-Descriptive Statistics of Achievement in Biology (ACHB).

Statistic	Value
N (Valid Cases)	257
Mean	0.064
Standard Deviation	0.956
Median	0.201
Minimum	-2.36
Maximum	1.77
Range	4.12
Skewness	-0.579
Kurtosis	-0.406
95% Confidence Interval (CI)	[-0.054, 0.181]

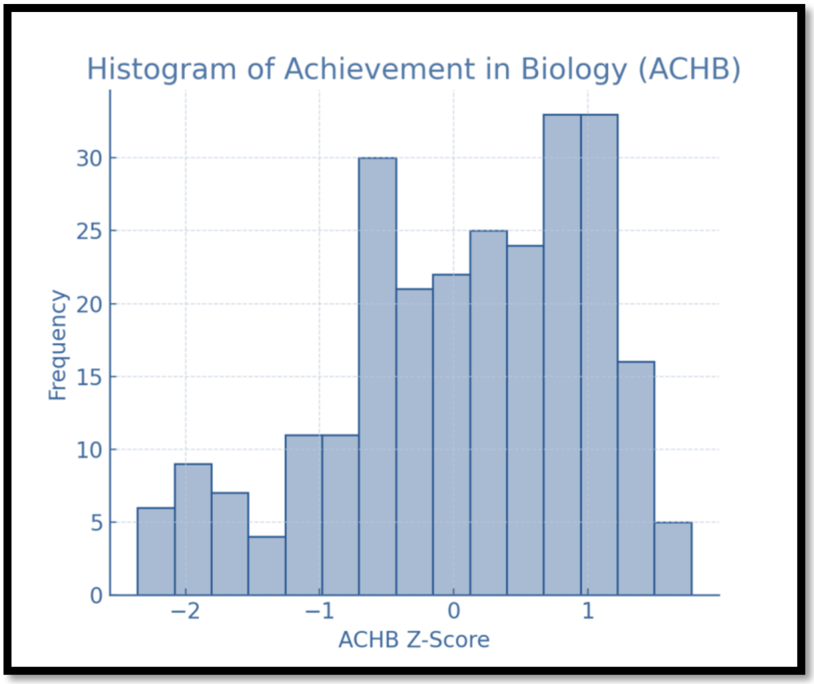

Fig. 3.16: - Histogram _ ACHB.

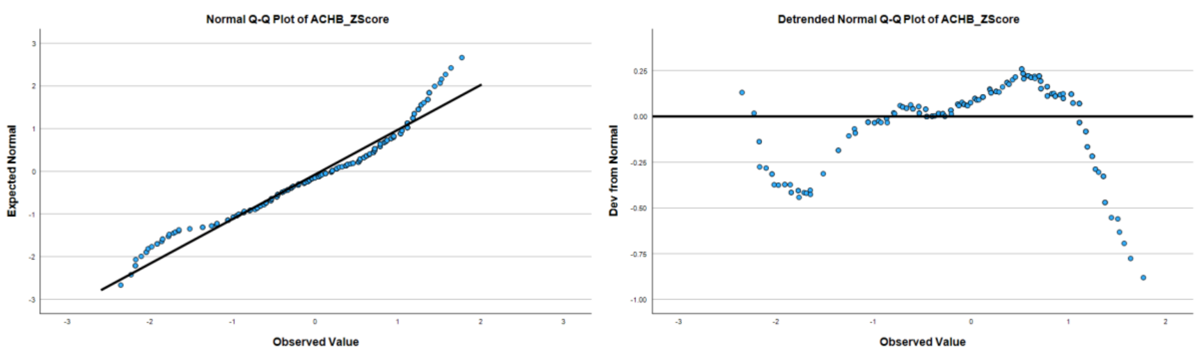

Fig. 3.17:- Normal and Dtrended Normal Q-Q Plot for ACHB_TOT.

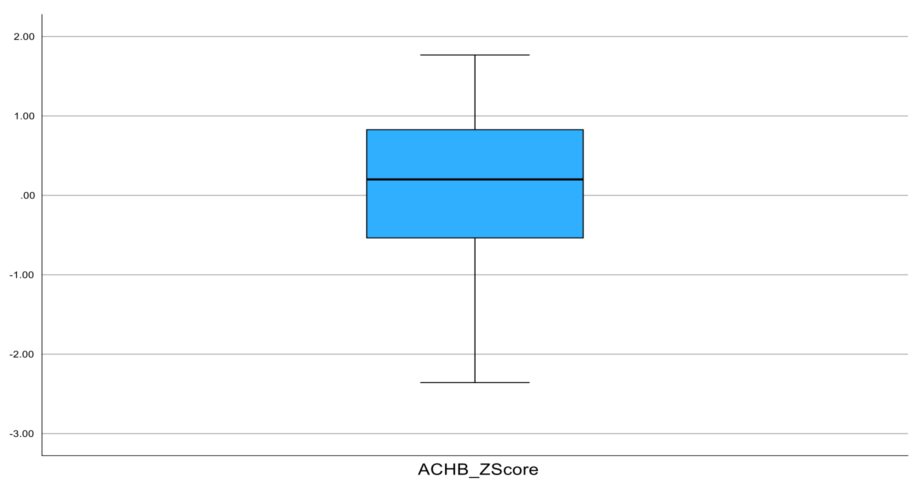

Fig. 3.18:- Box Plot ACHB_TOT.

Interpretation: Achievement scores (as Z-scores) are normally distributed and centered near 0, suggesting a balanced level of performance across the sample, with some outliers at both extremes.

By Gender

Table 3.11:-Group Statistics of Achievement in Biology (ACHB)_ Gender wise.

Gender	N	Mean	Std. Deviation	Std. Error Mean
Boys	158	0.0660	0.9906	0.0788
Girls	99	0.0597	0.9032	0.0908

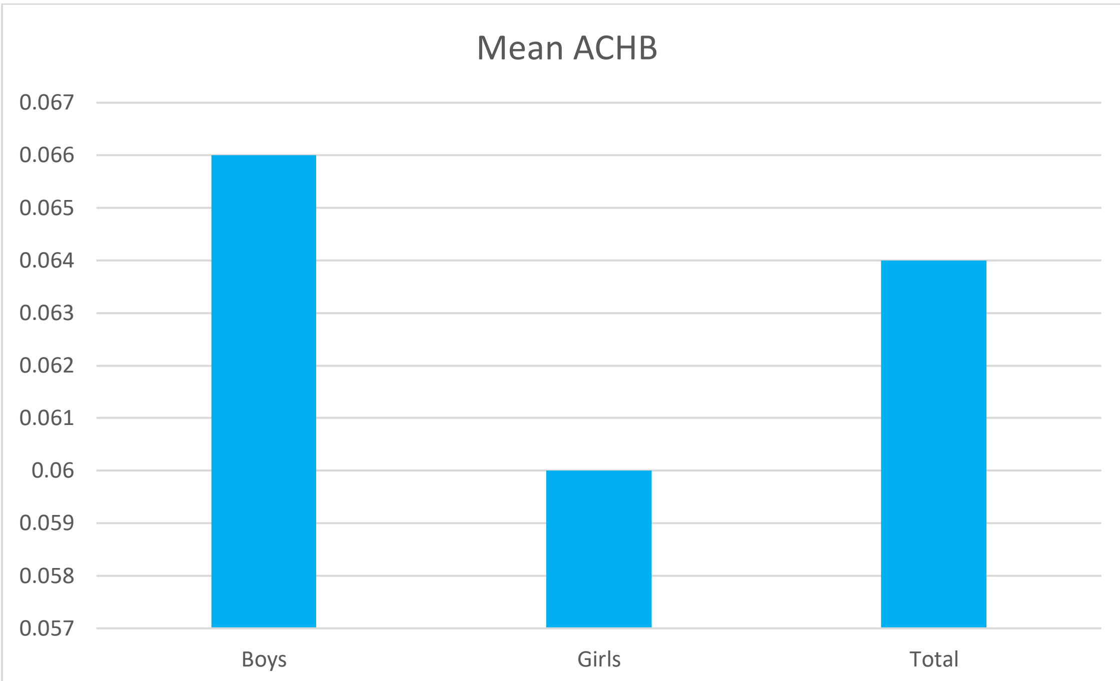

Fig. 3.19:- Group Statistics of ACHB _ Gender wise.

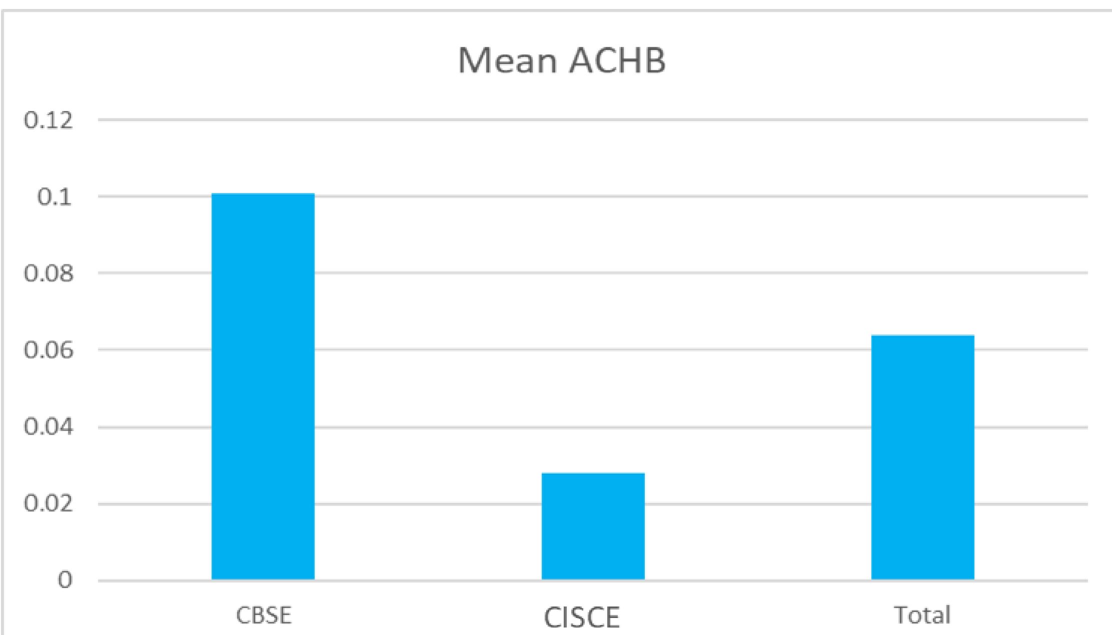

Fig. 3.20:- Group Statistics of ACHB _ Board wise.

By Board

Table 3.12:-Group Statistics of Achievement in Biology (ACHB)_ Board wise.

Board	N	Mean	Std. Deviation	Std. Error Mean
CBSE	124	0.1014	0.9239	0.0830
CISCE	133	0.0283	0.9874	0.0856

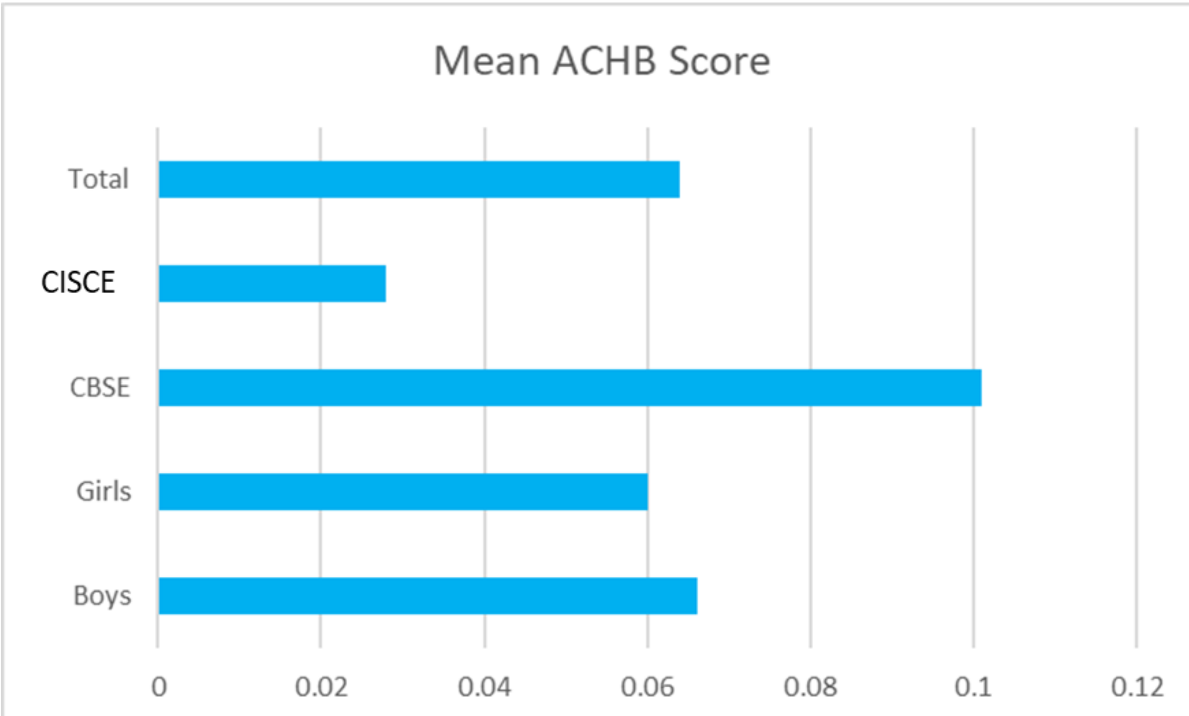

Fig. 3.21: - Overall Mean Score ACHB.

Descriptive Statistics of Major Variables

Table 3.13. Descriptive Statistics of Major Variables

Variable	Mean	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis
LMTB_TOT	118.74	17.89	73	160	-0.407	-0.534
UITSB_TOT	119.18	8.92	98	139	-0.023	-0.293
ACHB_ZScore	0.064	0.956	-2.36	1.77	-0.579	-0.406

These values suggest an approximately normal distribution for all three variables, validating the use of parametric tests.

Analyses and Interpretation

Software Used:

The raw data were tabulated in MS Excel 2024 and Analyses were done through SPSS 29.0 version.

Objective-Wise Data Analysis

Objective 1 (O1):

To measure the level ofUsage of Intelligent Tutoring Systemsof students studying at Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.1:-Group Statistics of UITSB _ Gender of Students.

Group	N	Mean	Std. Deviation
Boys	158	59.76	8.961
Girls	99	63.00	7.645
Total	257	61.01	8.547

Table 4.2:-Group Statistics of UITSB _ Board of Students.

Group	N	Mean	Std. Deviation
CBSE	124	64.13	7.397
CISCE	133	58.08	8.639
Total	257	61.01	8.547

Result:-

The **mean score** of UITSB = **119.18** (SD = 8.92).
This indicates a **moderate to high** level of digital content usage among students.

Interpretation:
Students are actively consulting and using Intelligent Tutoring Systemsfor learning Biology.

Objective 2 (O2):
To study the learning motivation towards Biology of students studying at Higher Secondary Level in Kolkata and the adjacent districts of West Bengal.

Table 4.3:-Group Statistics of LMTB _ Gender of Students.

Group	N	Mean	Std. Deviation
Boys	158	149.88	8.318
Girls	99	152.09	7.235
Total	257	150.96	7.858

Table 4.4:-Group Statistics of LMTB _ Board of Students.

Group	N	Mean	Std. Deviation
CBSE	124	152.24	7.127
CISCE	133	149.14	8.250
Total	257	150.96	7.858

Result:

The **mean score** of LMTB = **118.74** (SD = 17.89).
Indicates a **moderately positive** attitude towards Biology.

Interpretation:
Most students view Biology positively, likely influenced and motivated to study biology by accessibility to Intelligent Tutoring System.

Objective 3 (O3):
To measure the achievement in Biology of students studying at Higher Secondary Level in the southern districts of West Bengal.

Table 4.5: -Group Statistics of ACHB _ Gender of Students.

Group	N	Mean	Std. Deviation
Boys	158	-0.14	1.059
Girls	99	0.22	0.922
Total	257	0.00	1.031

Table 4.6:-Group Statistics of ACHB _ Board of Students.

Group	N	Mean	Std. Deviation
CBSE	124	0.43	0.704
CISCE	133	-0.39	1.048
Total	257	0.00	1.031

Result:
Mean Z-score of achievement (ACHB_ZScore) = **0.064** (SD = 0.956)
Distribution is **normal** (skewness = -0.579).

Interpretation:
Achievement is balanced across the sample; no extreme bias toward low or high scores.

Hypothesis Testing Using Inferential Statistics
$H_0$1: There is no significant difference in the level of usage of Intelligent Tutoring Systems (ITS) in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.
Table 4.7:-Group Statistics and Independent Sample Test of UITSB _ Boys vs Girls.

Group Statistics					**t-test for Equality of Means**		
Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
Boys	158	119.22	8.275	0.658	-0.082	255	0.935
Girls	99	119.12	9.899	0.995			

Interpretation:
From the analysis, in **Table 4.7.** it is observed that no statistically significant difference is found in Intelligent Tutoring System related to Biology (UITSB) between boys and girls, as the calculated $t_{(255)}$ value is -0.082 and p-value is 0.935 ($p > 0.05$). Therefore, the null hypothesis **H_o1** is accepted. It may be inferred that both boys and girls refer to Intelligent Tutoring System related to Biology at similar levels.

$H_0$2: There is no significant difference in students' learning motivation in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.
Table 4.8:-Group Statistics and Independent Sample Test of LMTB _ Boys vs Girls.

Group Statistics					**t-test for Equality of Means**		
Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
Boys	158	121.00	16.839	1.340	-2.583**	255	0.010
Girls	99	115.14	18.992	1.909			

Interpretation:
From the analysis, in **Table 4.8.** it is found that a statistically significant difference exists in Learning Motivation Towards Biology (LMTB) between boys and girls, with the calculated $t_{(255)}$ value being -2.583 and p-value being 0.010 ($p < 0.05$). Hence, the null hypothesis **$H_0$2** is rejected. It can be inferred that boys possess a more Learning Motivation towards Biology than girls.

$H_0$3: There is no significant difference in academic achievement in Biology between the boys and girls studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.
ACHB by Gender

Table 4.9. Group Statistics and Independent Sample Test of ACHB _ Boys vs Girls

Group Statistics					**t-test for Equality of Means**		
Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
Boys	158	0.0660	0.9906	0.0788	-0.051	255	0.959
Girls	99	0.0597	0.9032	0.0908			

Interpretation:
From the analysis in **Table 4.9.** it is observed that there is no statistically significant difference in Achievement in Biology (ACHB) between boys and girls, as the calculated $t_{(255)}$ value is -0.051 and p-value is 0.959 ($p > 0.05$). Thus, the null hypothesis **H_o3 (gender)** is accepted. It may be inferred that both boys and girls perform similarly in terms of academic achievement in Biology.

$H_0$4: There is no significant difference in the level of usage of Intelligent Tutoring Systems (ITS) in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.10:-Group Statistics and Independent Sample Test of UITSB _ CBSE vs CISCE.

Group Statistics					t-test for Equality of Means		
Board	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
CBSE	124	122.81	10.01	0.899	6.837^{**}	255	<0.001
CISCE	133	115.80	6.08	0.527			

Interpretation:
From the analysis of Table No. 4.10. it is evident that a significant difference exists in Usage of Intelligent Tutoring System related to Biology (UITSB) between CBSE and CISCE students, as the the calculated $t_{(255)}$ value is 6.837 p-value is less than 0.001 ($p < 0.05$). Therefore, the null hypothesis $H_0 4$ is rejected. It may be concluded that CBSE students make greater use of digital content for learning Biology in comparison to their CISCE counterparts. The significant result from Levene's Test confirms the presence of unequal variances, which were duly accounted for in the analysis.

$H_0$5: There is no significant difference in students' learning motivation in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.11:-Group Statistics and Independent Sample Test of LMTB _ CBSE vs CISCE.

Group Statistics					t-test for Equality of Means		
Board	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
CBSE	124	125.21	18.760	1.685	5.960^{**}	255	<0.001
CISCE	133	112.71	14.732	1.277			

Interpretation:
From the analysis, of the Table 4.11. a highly significant difference is noticed in Learning Motivation Towards Biology (LMTB) between CBSE and CISCE students, as the calculated $t_{(255)}$ value is 5.960 and the p-value is less than 0.001 ($p < 0.05$). Hence, the null hypothesis $H_0 5$ is rejected. It can be inferred that CBSE students possess more favourable learning motivation towards Biology compared to CISCE students, indicating that board affiliation influences students' motivation in learning toward the subject.

$H_0$6: There is no significant difference in academic achievement in Biology between the students studying in CISCE and CBSE Boards at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.12.: - Group Statistics and Independent Sample Test of ACHB _ CBSE vs CISCE.

Group Statistics					t-test for Equality of Means		
Board	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**t**	**df**	**Sig. (2-tailed) p**
CBSE	124	0.1014	0.9239	0.0830	0.611	255	0.542
CISCE	133	0.0283	0.9874	0.0856			

Interpretation:
From the analysis presented in Table 4.12., it is seen that there is no statistically significant difference in Achievement in Biology (ACHB) between CBSE and CISCE students, with the $t_{(255)}$ value being 0.611 and p-value being 0.542 ($p > 0.05$). Therefore, the null hypothesis **$H_0$6 (board)** is accepted. This suggests that academic performance in Biology does not vary significantly based on board affiliation.

One-Way ANOVA by Group (Girl/Boy × CBSE/CISCE)

$H_0$7: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their usage of Intelligent Tutoring Systems (ITS) in Biology at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.13:-ANOVA _ UITSB.

Source of Variation	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig. (p)**
Between Groups	3560.418	3	1186.806	17.880	<0.001
Within Groups	16793.348	253	66.377		
Total	20353.767	256			

(*Significant at 0.05 of significance)

Table 4.14:-Multiple Comparison Between Groups for UITSB.

(I) Strata status	(J) Strata status	Mean Difference (I–J)	Std. Error	Sig.
Girl CBSE	**Girl CISCE**	10.135*	1.284	<0.001
	Boy CISCE	6.922*	1.258	<0.001
Boy CBSE	**Girl CISCE**	8.347*	1.211	<0.001
	Boy CISCE	5.134	1.184	<0.001
Girl CISCE	**Girl CBSE**	-10.135*	1.284	<0.001
	Boy CBSE	-8.347*	1.211	<0.001
Boy CISCE	**Girl CBSE**	-6.922	1.258	<0.001
	Boy CBSE	-5.134*	1.184	<0.001

(*Significant at 0.05 of significance)

The post-hoc analysis		
Groups Compared	**Mean Difference (I-J)**	**Sig. (p)**
Girl CBSE – Girl CISCE	**10.135**	<0.001
Girl CBSE – Boy CISCE	**6.922**	<0.001
Boy CBSE – Girl CISCE	**8.347**	<0.001
Boy CBSE – Boy CISCE	**5.134**	<0.001

UITSB: Significant difference found across groups (F=17.88, p<0.001). **Significant at 0.05 level**.

Interpretation:

In the case of comparing the four subgroups—Girl CBSE, Girl CISCE, Boy CBSE, and Boy CISCE—with respect to their Usage of Intelligent Tutoring System in Biology (UITSB), the One-Way ANOVA analysis reveals that a statistically significant difference exists among the groups, as the calculated F-value is 17.88 and the corresponding p-value is less than 0.001 ($p < 0.05$). Hence, the null hypothesis $H_0 7$ is rejected, and it may be concluded that extent of usage of Intelligent Tutoring System varies significantly across the groups.

From the subsequent post hoc analysis for multiple comparisons, it is observed that CBSE students, particularly girls, consume digital content at a significantly higher level than their CISCE counterparts. The result indicates that both gender and educational board affiliation play a role in shaping the extent of referring to ITS platforms for academic resourcesconsultation, possibly due to disparities in accessibility, curriculum emphasis, or digital literacy patterns across groups.

$H_0$8: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their learning motivation in Biology at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.14: -ANOVA _ LMTB.

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. (p)
Between Groups	13852.580	3	4617.527	17.154	<0.001
Within Groups	68102.471	253	269.180		
Total	81955.051	256			

(*Significant at 0.05 of significance)

Table 4.16:- Multiple Comparison Between Groups for LMTB.

(I) strata status	(J) strata status	Mean Difference (I–J)	Std. Error	Sig.
Girl CBSE	Girl CISCE	17.766*	2.413	<0.001
	Boy CISCE	6.936	2.413	0.096
Boy CBSE	Girl CISCE	20.933*	2.331	<0.001
	Boy CISCE	10.104*	2.331	<0.001
Girl CISCE	Girl CBSE	-17.766*	2.413	<0.001
	Boy CBSE	-20.933*	2.331	<0.001
Boy CISCE	Girl CBSE	-6.936	2.413	0.096
	Boy CBSE	-10.104*	2.331	<0.001

(*Significant at 0.05 of significance)

The post-hoc analysis		
Groups Compared	**Mean Difference (I-J)**	**Sig. (p)**
Girl CBSE – Girl CISCE	**17.766**	<0.001
Girl CBSE – Boy CISCE	**6.936**	0.096
Boy CBSE – Girl CISCE	**20.933**	<0.001
Boy CBSE – Boy CISCE	**10.104**	<0.001

LMTB: Significant difference found ($F=17.15$, $p<0.001$). **Significant at 0.05 level.**

Interpretation:
In the case of comparing learning motivation towards Biology (LMTB) among the groups—Girl CBSE, Girl CISCE, Boy CBSE, and Boy CISCE—a statistically significant difference is found, as revealed by the One-Way ANOVA with an F-value of 17.15 and a p-value of less than 0.001 ($p < 0.05$). Thus, the null hypothesis **$H_0$8** is rejected, and it can be inferred that learning motivation towards Biology differ significantly among the groups.

The post hoc analysis indicates that both CBSE girls and boys exhibit a more favourable attitude towards Biology compared to CISCE girls. A particularly notable difference is observed between Girl CBSE and Girl CISCE (mean difference = 17.766), as well as between Boy CBSE and Girl CISCE, both of which are statistically significant. These findings suggest that the curriculum design, exposure to subject content, or pedagogical strategies within the CBSE system may contribute to more positive motivation of the students towards learning the subject.

$H_0$9: There is no significant difference among the groups of students considering gender and board of study taken together (boys of CISCE board, boys of CBSE board, girls of CISCE board, girls of CBSE board) in their academic achievement in Biology at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.15: - ANOVA_ACHB

Source of Variation	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig. (p)**
Between Groups	3.914	3	1.305	1.434	0.233
Within Groups	230.105	253	0.910		
Total	234.018	256			

(*Significant at 0.05 of significance)

All pairwise comparisons are not statistically significant ($p> 0.05$).
Thus, there are no meaningful differences in achievement across any of the four subgroups. It can be said that there is no significant difference among the groups in their achievement in Biology. Therefore, the subsequent post Hoc analysis is not required.

Interpretation:
In comparing Achievement in Biology (ACHB_ZScore) as per Table No. 4.17. among the four subgroups—Girl CBSE, Girl CISCE, Boy CBSE, and Boy CISCE—the results of the One-Way ANOVA indicate that no statistically significant difference exists among the groups, as the calculated F-value is 1.434 and the p-value is 0.233 ($p > 0.05$). Therefore, the null hypothesis $H_0$9 is accepted, and it is concluded that academic achievement in Biology does not differ meaningfully across gender and board affiliation.

$H_0$10: There is no significant relationship between the usage of Intelligent Tutoring Systems (ITS) in Biology and students' learning motivation in Biology among students studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.16: - Correlations UITSB _ LMTB.

Correlations			
		UITSB_TOT	**LMTB_TOT**
UITSB_TOT	Pearson Correlation	1	0.240**
	Sig. (2-tailed)		<0.001
	N	257	257
LMTB_TOT	Pearson Correlation	0.240**	1
	Sig. (2-tailed)	<0.001	
	N	257	257
** Correlation is significant at the 0.01 level (2-tailed).			

Variables	Pearson Correlation (r)	Sig. (2-tailed)	N
UITSB_TOT ↔ LMTB_TOT	**0.240**	**<0.001**	**257**

Interpretation:
The analysis in **Table 4.16.** shows that the correlation coefficient (‘r’) between Usage of Intelligent Tutoring System (UITSB) and Learning Motivation Towards Biology (LMTB) is 0.240, with a p-value less than 0.001 ($p < 0.05$), which is statistically significant. Hence, **$H_0$10** is rejected. This indicates a weak positive correlation between usage of intelligent tutoring system and students’ learning motivation towards Biology at the higher secondary level.

$H_0$11: There is no significant relationship between the usage of Intelligent Tutoring Systems (ITS) in Biology and academic achievement in Biology among students studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.17: - Correlations UITSB _ ACHB.

Correlations			
		UITSB_TOT	**ACHB_ZScore**
UITSB_TOT	Pearson Correlation	1	0.073
	Sig. (2-tailed)		0.245
	N	257	257
ACHB_ZScore	Pearson Correlation	0.073	1
	Sig. (2-tailed)	0.245	
	N	257	257
** Correlation is significant at the 0.01 level (2-tailed).			

Variables	Pearson Correlation (r)	Sig. (2-tailed)	N
UITSB_TOT ↔ ACHB_ZScore	**0.073**	**0.245**	**257**

Interpretation:
The analysis in **Table 4.17.** shows that the correlation coefficient (‘r’) between Intelligent Tutoring System (UITSB) and Academic Achievement in Biology (ACHB) is 0.073, with a p-value of 0.245 ($p > 0.05$), which is not statistically significant. Hence, **$H_0$11** is accepted. This indicates that there is no significant correlation between usage of Intelligent Tutoring System and students’ academic achievement in Biology at the higher secondary level.

$H_0$12: There is no significant relationship between students’ learning motivation in Biology and their academic achievement in Biology among students studying at the Higher Secondary Level in Kolkata and adjacent districts of West Bengal.

Table 4.18: - Correlations LMTB _ ACHB.

Correlations			
		LMTB_TOT	**ACHB_ZScore**
LMTB_TOT	Pearson Correlation	1	0.488**
	Sig. (2-tailed)		<0.001
	N	257	257
ACHB_ZScore	Pearson Correlation	0.488**	1
	Sig. (2-tailed)	<0.001	
	N	257	257
** Correlation is significant at the 0.01 level (2-tailed).			

Variables	**Pearson Correlation (r)**	**Sig. (2-tailed)**	**N**
LMTB_TOT ↔ ACHB_ZScore	**0.488**	**<0.001**	**257**

Interpretation:
Table 4.18. shows that the correlation coefficient (‘r’) between Learning Motivation Towards Biology (LMTB) and Academic Achievement in Biology (ACHB) is 0.488, with a p-value less than 0.001 ($p < 0.05$), which is statistically significant. Hence, **$H_0$12** is rejected. This indicates a moderate positive correlation between students’ Learning Motivation towards Biology and their academic achievement at the higher secondary level.

Summary of the Correlation(s):
Table 4.19: -Summary of Correlations.

Correlated Variables	**r**	**Sig.**	**Interpretation**
UITSB_TOT & LMTB_TOT	0.240	<0.001	Significant, weak positive
UITSB_TOT &ACHB_ZScore	0.073	0.245	Not significant
LMTB_TOT &ACHB_ZScore	0.488	<0.001	Significant, moderate positive

Variables	**UITSB_TOT**	**LMTB_TOT**	**ACHB_ZScore**
UITSB_TOT	1	0.240**	0.073
LMTB_TOT	0.240**	1	0.488**
ACHB_ZScore	0.073	0.488**	1

Strength of Correlation according to r-value:

r value	**Strength of Correlation**
0.00–0.19	Very weak
0.20–0.39	Weak
0.40–0.59	Moderate
0.60–0.79	Strong
0.80–1.00	Very strong

Summary of the Analyses and Interpretations:
Table 4.20:-Summary of the Analyses and Interpretations

Objective	**Tested Variable(s)**	**Outcome**
O1	UITSB Total Score	Moderate-High Usage
O2	LMTB Total Score	Moderately Positive Attitude
O3	ACHB Z-Score	Balanced, Normal Distribution
O4	UITSB: Boys vs Girls	No Significant Difference
O5	LMTB: Boys vs Girls	Boys More Positive (Significant)
O6	ACHB: Boys vs Girls	No Significant Difference
O7	UITSB: CBSE vs CISCE	CBSE Higher Usage (Significant)
O8	LMTB: CBSE vs CISCE	CBSE More Positive (Significant)

O9	ACHB: CBSE vs CISCE	No Significant Difference
O10	Correlations (UITSB, LMTB, ACHB)	LMTB ↔ ACHB Strong; UITSB ↔ LMTB Moderate

Discussion: -

Major Findings

This study aimed to examine the impact of Intelligent Tutoring Systems (ITS) on higher secondary students' learning motivation and academic achievement in Biology, with a focus on students from the southern districts of West Bengal affiliated with the CBSE and CISCE Boards. The key findings indicate that although students report moderately high usage of ITS, its influence is more pronounced on learning motivation than on direct academic performance. Furthermore, students with higher motivation levels tend to achieve better outcomes. Gender- and board-wise analyses also reveal notable differences in digital learning behaviours and motivational patterns. However, the study's reliance on self-reported ITS usage data and the lack of distinction between different types or quality of ITS platforms limit the depth of technical insights into which platform features most effectively drive these outcomes.

Findings Related to Students' Learning Motivation Towards Biology

The analysis showed that the mean learning motivation score was moderately positive ($M = 118.74$, $SD = 17.89$), suggesting that most students held a favourable view of Biology as a subject. A significant gender difference was observed, where boys exhibited higher motivation levels than girls ($p = 0.010$). This aligns with findings by Tarng & Tsai (2012) and Gupta & Reddy (2020), which emphasized the role of digital content in stimulating student motivation. Furthermore, students from the CBSE Board showed significantly higher motivation than their CISCE counterparts ($p < 0.001$). This could be attributed to CBSE's relatively stronger integration of digital platforms and emphasis on self-paced learning resources, including ITS.

Findings Related to Students' Academic Achievement in Biology

The academic achievement scores, transformed into standardized Z-scores ($M = 0.064$, $SD = 0.956$), showed a balanced and normally distributed performance across the sample. Notably, no significant gender-based or board-based differences were found in achievement ($p > 0.05$). This implies that despite variations in digital content usage and motivation, academic outcomes remained consistent across demographic groups. This finding resonates with studies like Bhalerao & Khot (2016) and Cheung & Slavin (2013) which observed that while digital content may enhance engagement and attitudes, achievement outcomes may depend on other factors such as prior knowledge, teaching quality, and assessment methods.

This finding suggests that while motivation and ITS usage vary, actual academic performance remains statistically consistent across gender and board affiliations. This outcome can be interpreted in multiple ways:

- It may suggest that classroom teaching and traditional assessment patterns still play the dominant role in influencing achievement.
- It could indicate that students compensate differently—those with lower ITS exposure or motivation may invest more effort in traditional study methods.
- Alternatively, it might imply that achievement tests measure knowledge retention more than skill-based or applied understanding, which ITS is designed to improve.

Findings Related to Learning Motivation Across Groups

A four-group ANOVA comparison among Girl CBSE, Girl CISCE, Boy CBSE, and Boy CISCE revealed significant differences in learning motivation ($F = 17.15$, $p < 0.001$). Post hoc analysis indicated that CBSE students of both genders scored significantly higher, with Girl CISCE students exhibiting the lowest motivation levels. This reinforces the impact of curriculum delivery models and digital readiness on students' affective engagement with the subject. The CBSE system, with greater exposure to ICT-based pedagogies, likely facilitates a more engaging and autonomous learning experience.

Findings Related to Learning Motivation and Academic Achievement

A moderate positive correlation ($r = 0.488$, $p < 0.001$) was found between learning motivation and academic achievement, indicating that students who are more motivated toward Biology tend to perform better academically. This is in agreement with Ajzen's **Theory of Planned Behavior (1991)**, which posits that attitude and motivation influence goal-directed behaviours such as academic effort. The result also supports findings by Bhalerao & Khot (2016) and Dutta (2025), where motivation acted as a mediating factor in academic performance.

Findings Related to the Usage of ITS

The mean score for ITS usage (UITSB) was moderately high (M = 119.18, SD = 8.92), indicating that students are increasingly adopting ITS platforms for learning Biology. No significant gender difference was noted in ITS usage, suggesting equal digital engagement among boys and girls. However, CBSE students reported significantly higher usage than CISCE students ($p < 0.001$), consistent with board-level differences in ICT integration.

ANOVA analysis revealed significant group-wise variation ($F = 17.88$, $p < 0.001$), with CBSE girls using ITS most extensively, followed by CBSE boys. These findings are in line with VanLehn (2011) and Graesser et al. (2012), who highlighted that students using ITS engage more with self-regulated learning and interactive content.

Further, a weak but significant positive correlation ($r = 0.240$, $p < 0.001$) was found between ITS usage and learning motivation, indicating that while ITS might not directly influence achievement, it positively affects how students feel about the subject. However, no significant correlation was found between ITS usage and actual academic performance ($r = 0.073$, $p = 0.245$), suggesting that ITS tools alone may not suffice for boosting academic scores unless supported by structured pedagogy and student guidance.

Relationship Between ITS Usage, Motivation, and Achievement

The correlation analysis offered deeper insights into the interconnectedness of key variables:

- A moderate positive correlation ($r = 0.240$, $p < 0.001$) was found between ITS usage and learning motivation, indicating that students who engage more with ITS platforms tend to develop a more positive disposition towards Biology. This is consistent with findings by Tarng & Tsai (2012) and Roll et al. (2014), who highlighted the motivational potential of interactive and adaptive learning technologies.
- However, no significant correlation ($r = 0.073$, $p = 0.245$) was found between ITS usage and academic achievement, suggesting that mere exposure to or frequency of ITS use may not translate directly into higher academic scores. This supports VanLehn (2011), who emphasized that the effectiveness of ITS varies with implementation fidelity and student regulation.
- A moderate positive correlation ($r = 0.488$, $p < 0.001$) was found between learning motivation and academic achievement, reinforcing the theory that motivated students are more likely to perform well academically. This finding is congruent with Ajzen's Theory of Planned Behavior (1991), which posits that intention (driven by motivation) predicts behavior (such as academic effort and performance).

Together, these results suggest that ITS platforms are more effective in enhancing affective engagement than in directly improving academic outcomes, unless combined with broader pedagogical strategies.

Synthesis and Implications

The findings of the present study reinforce the idea that technology by itself is not a magic bullet for academic success. ITS platforms are powerful tools for increasing interest, motivation, and engagement, especially when used within a supportive educational framework that includes guided instruction, regular feedback, and curriculum alignment.

The board-wise disparities indicate the need for standardized policy initiatives to ensure equitable digital integration across education systems. While CBSE appears to offer better digital readiness, CISCE may need targeted intervention to bridge the motivation and usage gap.

Gender differences in motivation, despite similar achievement levels and ITS usage, point to underlying psychosocial factors that could be addressed through mentoring, teacher training, and inclusive content design.

Alignment with Prior Research

The current study's findings are in broad alignment with past literature:

- It supports the work of **Graesser et al. (2012)** and **Chou et al. (2021)**, who found that **dialogic and ITS-enhanced instruction improves engagement and concept clarity**, if not always raw academic scores.
- The study corroborates **Patil & Patil (2018)** and **Schmid et al. (2014)** in asserting that digital tools have a measurable impact on **student motivation and learning process**.

- However, it departs from studies like Hwang et al. (2020), where AR-based ITS led to direct improvement in lab performance—suggesting that context, tool design, and subject area matter significantly in determining ITS impact.

Table 5.1: -Literature Review Matrix - About Major Discussion Found by the Present Researcher Through Review of Literature.

Published by	**Location**	**Year**	**Attitude towards Biology (Boys–Girls)**	**Achievement in Biology (Boys–Girls)**	**Board-wise Difference**	**Correlation of Attitude &Achievement**
Nelliappan, N.O.	Tamil Nadu	1992	✓	–	–	–
Malvya& Dharma, Shila	Madhya Pradesh	1991	✓	–	–	–
Ghosh, Shibani	Andhra Pradesh	1989	✕	–	–	–
Kumar, Udaya Sam	Tamil Nadu	1991	✓	–	✕	● (+)
Kar, D.K.	Odisha	1990	✕	✕	–	● (+)
Sharma & Sharma	India	2018	–	–	Digital use ↑	● (Implied +)
Patil & Patil	India	2018	–	–	Digital use ↑	● (Implied +)
Gupta & Reddy	India	2020	Digital use ↑	Digital use ↑	Usage frequency ↑	● (+)
Lin & Hwang	Taiwan	2010	Multimedia ↑	↑	–	● (+)
Present Study	West Bengal (CBSE &CISCE)	**2025**	✓	✕	**✓ (CBSE >CISCE)**	**● ($r = 0.488$, $p < 0.01$)**

Legend:
- **✓ = Significant difference**
- **✕ = No significant difference**
- **– = Not studied / Not reported**
- **↑ = Positive impact**
- **● = Positive correlation**

Observations from the Comparison:

1. **Gender-based Attitude Towards Biology:**

o Several earlier studies (e.g., Nelliappan, Malvya& Dharma, Kumar) found significant differences in attitude towards Biology between boys and girls.

o The present study also supports this trend, showing boys to have significantly higher learning motivation towards Biology than girls.

o Contrarily, Ghosh and Kar reported no significant gender difference, indicating inconsistencies across contexts and times.

2. **Gender-based Achievement in Biology:**
- Most earlier studies either did not explore this aspect or reported no significant gender difference (e.g., Kar).
- The present study aligns with this, showing no significant difference in achievement between boys and girls.

3. **Board-wise Differences:**
- Limited earlier literature addressed board-based differences in digital usage or learning outcomes.
- The present study fills this gap, revealing significant differences in both ITS usage and learning motivation, with CBSE students outperforming CISCE counterparts, likely due to curriculum and tech integration differences.
- Kumar's study had indicated a lack of significant board differences, but that was not in the context of digital content.

4. **Impact of Digital Content Usage:**
- Studies like Sharma & Sharma, Patil & Patil, and Gupta & Reddy reported positive impacts of digital content on attitude and achievement, echoing the current findings.
- Lin & Hwang also highlighted multimedia-based instruction as beneficial, particularly in boosting motivation and performance.
- The present study reinforces this trend by linking higher ITS usage with improved motivation, though no direct correlation was found with achievement.

5. **Correlation Between Attitude and Achievement:**
- Both earlier (Kumar, Kar) and current studies reported a significant positive correlation between students' attitude towards Biology and their academic achievement.
- This suggests that motivation acts as a bridge between engagement with content (like ITS) and measurable academic success.

Educational Implications:

1. **ITS as a Motivational Tool:**
- The study shows a moderate to strong correlation between ITS usage and learning motivation.
- Schools should integrate ITS-based modules in Biology classes to foster higher student engagement and motivation.

2. **Board-Level Curriculum Reforms:**
- CBSE students showed higher ITS usage and more favourable motivation than CISCE students.
- Curriculum planners in CISCE could incorporate more digital content and ITS-friendly structure to bridge the digital pedagogical gap.

3. **Gender-Sensitive Intervention:**
- Boys showed significantly higher motivation towards Biology than girls.
- Educators should implement gender-sensitive strategies, including mentorship, female role models in STEM, and interactive ITS content appealing to diverse learners.

4. **ITS Training for Teachers and Students:**
- Despite moderate usage, the impact on achievement was not significant, suggesting a **need for structured guidance** in using ITS tools effectively.
- **Capacity building** workshops for teachers and digital literacy sessions for students can enhance effective ITS integration.

5. **Prioritizing Motivation to Boost Achievement:**
- A strong correlation between learning motivation and achievement suggests that improving motivation (possibly via ITS) could indirectly uplift academic outcomes.
- School strategies should include motivational modules**,** career talks, and real-life biology applications alongside digital learning tools.

Limitations of the Present Study:

Although the study provides significant contributions to the understanding of digital content usage and ITS in Biology education, several limitations affect the breadth and generalizability of its findings:

1. **Geographical Scope:**
   The study was conducted exclusively in the southern districts of West Bengal. This narrow regional focus limits the applicability of the results beyond this context and may not reflect the diversity of educational experiences in other parts of India or globally.
2. **Limited Board Representation:**

The participant pool included only students affiliated with CBSE and CISCE. The exclusion of other boards such as WBCHSE, NIOS, and international curricula restricts the generalizability of the findings. Educational practices and access to ITS tools may differ significantly across these systems.

3. **Cross-Sectional Research Design:**
   The study utilized a cross-sectional survey method, which captures data at a single time point. Consequently, it cannot assess longitudinal changes in students' learning motivation or achievement due to prolonged exposure to ITS.
4. **Reliance on Self-Reported Data:**
   Data on ITS usage were gathered through self-reported tools, which are vulnerable to biases such as overreporting, underreporting, and social desirability effects, potentially affecting the accuracy of the findings.
5. **Lack of Differentiation Among ITS Platforms:**
   The study did not distinguish between different types of ITS platforms or analyse their individual characteristics—such as interactivity, content quality, and usage duration—which could differentially impact learning outcomes.

Overall, the study's regional concentration and board-specific sampling limit the extent to which the findings can be generalized nationally or internationally. Broader and more inclusive research is needed to validate and extend these results.

Suggestions for Future Study:-

To overcome the limitations noted above and deepen the understanding of ITS impacts in Biology education, future studies are advised to consider the following directions:

Adoption of Longitudinal Designs:

Long-term studies tracking students across academic years can reveal sustained effects of ITS use on motivation and achievement, offering insights beyond the constraints of cross-sectional analysis.

Expanded Representation Across Boards and Regions:
Future research should involve students from a wider range of educational boards—including State Boards, NIOS, and international curricula—as well as diverse geographical regions across India. This will help produce findings that are more representative and generalizable at both national and international levels.

Qualitative and Mixed-Methods Approaches:
Incorporating qualitative interviews or mixed-method research can uncover nuanced reasons behind the differential impacts of ITS on motivation versus achievement, as perceived by students and educators.

Comparative Studies of ITS Platforms:
Research comparing specific ITS platforms (e.g., BYJU'S, Khan Academy, NEET Prep) could identify which features—such as adaptive learning, gamification, or content specificity—most effectively support Biology learning.

Experimental and Intervention-Based Designs:
Using controlled experimental setups with structured interventions can provide stronger evidence of causality between ITS usage and student outcomes, enabling more reliable conclusions for policy and practice.

Interdisciplinary and Holistic Scope:
Extending the research focus to include other science subjects such as Chemistry and Environmental Science will support the development of holistic digital learning environments that better reflect real-world scientific interconnectivity.
In sum, future research must adopt broader, more inclusive, and methodologically diverse approaches to meaningfully generalize the benefits of ITS across varied educational settings.

Conclusion:-

The present study was undertaken to examine the influence of Intelligent Tutoring Systems (ITS) on students' learning motivation and academic achievement in Biology at the higher secondary level. With the rapid advancement of educational technology, ITS platforms have emerged as transformative tools capable of personalizing learning, particularly in complex science subjects like Biology. Grounded in this context, the study investigated not only the general usage patterns of ITS among students but also its differential impact across gender and board affiliation (CBSE and CISCE), and its correlations with motivation and achievement outcomes.

The findings revealed that students reported a moderate to high level of ITS usage, reflecting growing acceptance of digital platforms for academic support in Biology. A moderately positive learning motivation was also observed, with boys and CBSE-affiliated students displaying slightly higher motivation levels. However, academic achievement showed no significant differences across gender or board affiliation, indicating a degree of consistency in performance despite variation in motivation and digital engagement.

One of the key outcomes of the study was a moderate positive correlation between ITS usage and learning motivation, suggesting that increased interaction with ITS tools may foster greater interest and more positive attitudes toward the subject. However, ITS usage did not exhibit a significant direct impact on academic achievement, implying that while such platforms may enhance engagement and conceptual understanding, achievement is likely influenced by a broader set of instructional, cognitive, and contextual factors. In contrast, learning motivation demonstrated a moderately strong positive correlation with academic achievement, underscoring the critical role of motivational factors in educational success.
It is important to note that the study relied on self-reported data for measuring ITS usage, which may introduce bias and limit the precision of usage patterns. Furthermore, the study did not distinguish between types, features, or quality of ITS platforms, thereby restricting deeper insights into which platform characteristics most effectively support learning outcomes.

Overall, the study underscores the potential of ITS as a supportive tool in contemporary Biology education, particularly in fostering student motivation. Its implications are relevant for curriculum designers, educators, and policymakers seeking to promote more effective integration of ITS in classrooms and to bridge digital disparities across learner groups and educational boards. While the research provides valuable insights, it also opens important avenues for further investigation—particularly regarding longitudinal effects, qualitative learner experiences, and comparative analyses of platform-specific efficacy.

In conclusion, the findings affirm that Intelligent Tutoring Systems can play a constructive role in shaping students' motivation toward Biology. With sustained and inclusive implementation, these tools hold significant promise for enriching science education at the higher secondary level.

Appendices
Tool 1: UITSB
Each question uses a 5-point Likert scale, where:

- 1 = Strongly Disagree
- 2 = Disagree
- 3 = Neutral
- 4 = Agree
- 5 = Strongly Agree

Opinionnaire/ Questionnaire on Digital Content Consumption in Biology
(A questionnaire with 32 questions designed to quantify the digital content consumption of Class 11 biology students in West Bengal.)

Demographic Information:
Age: ______
Gender: ______
School Name: ______
Type of School (Board):[ ] CISCE Board [ ] CBSE Board [ ] Other (please specify) **______**
Locality:[ ] Rural [ ] Urban

- **Instruction for the Respondent:** Read each statement and carefully mark the one response that most clearly represents your agreement.

Sl. No.	Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	I have access to Intelligent Tutoring Systems (ITS) for learning biology.					
2	I regularly use ITS platforms to study biology topics.					
3	ITS provides personalized feedback that helps me understand biology better.					
4	I prefer using ITS over traditional methods for difficult biology concepts.					
5	ITS motivates me to study biology more regularly.					
6	I find it difficult to navigate or use ITS platforms.					
7	The adaptive nature of ITS helps address my individual learning needs in biology.					
8	ITS helps me to learn biology at my own pace.					
9	ITS tools help me prepare better for biology exams and tests.					
10	I feel more confident in biology after using ITS.					
11	I rarely find ITS useful in understanding biology concepts.					
12	I use ITS platforms to complete biology homework and assignments.					
13	I use ITS-based biology simulations to understand experiments and lab work.					
14	ITS makes biology learning more interesting and engaging.					
15	I find it easy to track my learning progress using ITS tools.					
16	I often receive support and suggestions from my teachers regarding the use of ITS.					
17	The ITS tools I use align well with the Class XI Biology curriculum.					
18	ITS platforms help me apply biology concepts to real-life situations.					
19	I face connectivity or technical issues while using ITS platforms.					
20	I believe the use of ITS improves my academic achievement in biology.					
21	I use ITS to revise biology lessons and review previously studied topics.					
22	I often use ITS outside of school hours to continue learning biology.					
23	I avoid using ITS as it is too complex to operate.					
24	The content in ITS tools is well-structured and easy to understand.					
25	ITS helps me develop problem-solving and critical thinking skills in biology.					
26	I rely on ITS more than textbooks for concept clarity in biology.					
27	I participate in ITS-based interactive activities like quizzes or virtual labs.					
28	ITS platforms reduce my need to ask teachers for help in biology.					
29	I believe ITS is essential for modern biology learning.					

30	I would recommend ITS to my peers as a useful tool for studying biology.					

____
Signature of the Student

Appendix - 2
Date: ___________________

Tool 2: LMTB
Rating Scale - Use the following 5-point Likert scale for responses:

- 1 = Strongly Disagree
- 2 = Disagree
- 3 = Neutral
- 4 = Agree
- 5 = Strongly Agree

Attitude Towards Biology Opinionnaire/ Questionnaire
(This questionnaire should be able to give a comprehensive view of students' attitudes towards biology, covering interest, perceived importance, self-efficacy, enjoyment, perceived difficulty, instructional quality, and future orientation.)

Demographic Information:
Age: ______
Gender: ______
School Name: ______
Type of School (Board):[ ] CISCE Board [ ] CBSE Board [ ] Other (please specify) ______
Locality:[ ] Rural [ ] Urban

• **Instruction for the Respondent:** Read each statement and carefully mark the one response that most clearly represents your agreement.

Sl	**Statements**	**Strongly Agree**	**Agree**	**Neutral**	**Disagr**	**Strongl Disagre**
1	I feel enthusiastic about learning biology.					
2	I feel a strong desire to learn more about biology topics.					
3	I set goals for what I want to learn in biology.					
4	I study biology because I genuinely enjoy the subject.					
5	I put extra effort into biology because I want to perform well.					
6	I often explore biology topics outside of my school syllabus.					
7	I enjoy solving challenging problems in biology.					
8	I find it satisfying to complete difficult biology tasks successfully.					
9	I take pride in my achievements in biology.					
1(	I continue studying biology even when					

	the content becomes difficult.					
11	I feel bored when I study biology.					
12	I often avoid studying biology unless it is absolutely necessary.					
13	I give up easily when I find biology topics hard to understand.					
14	I study biology only for the sake of exams.					
15	I am confident in my ability to learn biology.					
16	I find the biology content in my textbooks and class to be engaging.					
17	I look forward to biology lessons in school.					
18	I feel motivated when my teacher appreciates my efforts in biology.					
19	Group discussions in biology class increase my interest in the subject.					
20	I enjoy applying biology knowledge to real-world situations.					
21	I keep trying until I fully understand a biology concept.					
22	I use various resources like videos, apps, and notes to learn biology better.					
23	I feel encouraged when I see improvement in my biology test scores.					
24	I feel stressed when studying biology.					
25	My motivation in biology increases when I perform well in practicals.					
26	I take responsibility for my own learning in biology.					
27	I enjoy completing biology projects and assignments.					
28	I am eager to participate in biology-related competitions or events.					
29	I stay focused and attentive during biology classes.					
30	I think learning biology will help me achieve my long-term goals.					
31	I am motivated to pursue a career in a biology-related field.					
32	I would recommend biology to others as a subject worth learning.					

Signature of the Student

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