




Undergraduate Students' Intrinsic Motivation and Learning Outcome in General Genetics (BTC 214) Using Technology-Mediated Synchronous and Asynchronous Learning Approaches

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Abstract

This study investigates how technology-mediated learning, specifically synchronous (real-time) and asynchronous (self-paced) approaches, impacts undergraduate students' intrinsic motivation and learning outcomes in a general genetics course (BTC 214). The research design adopted in this study is a quasi-experimental, non-randomized, pre-test/post-test, control-group design. The Intrinsic Motivation Scale (IMS) and General Genetics Learning Outcome Test (GGLOT) are the instruments used for data collection. IMS and GGLOT were validated and trial-tested, yielding reliability values of 0.89 and 0.94, respectively, using Cronbach's alpha and the Kuder-Richardson (KR-21) formula. This quasi-experimental study employed a convenience sample of intact class groups, comprising all 137 undergraduate students enrolled in Biology and Biology Education (200 level) at Federal University Lokoja, Nigeria during the 2024/2025 session. Four research questions and four null hypotheses guided the study. The research questions were answered using *M* and *SD* scores, and the null hypotheses were tested using analysis of covariance. It was established among others that there was a significant difference in the mean intrinsic motivation ratings and learning outcome scores of undergraduate students taught general genetics using synchronous learning approach (SLA), asynchronous learning approach (ALA), and modified lecture method (MLM) $F(2, 130) = 95.06, p < .05$ and $F(2, 130) = 164.00, p < .05$ respectively. It was recommended that lecturers be encouraged to use technology-mediated pedagogies (TMPs), such as SLA and ALA, to elevate undergraduate students' intrinsic motivation and learning outcomes in general genetics.

Keywords: technology-mediated pedagogies, synchronous learning approach, asynchronous learning approach, intrinsic motivation, learning outcome, general genetics course (BTC 214)

Introduction

The digital era presents new and expanded opportunities for technology-mediated pedagogies (TMPs), teaching methods that incorporate digital tools and resources to enhance the learning experience. TMPs foster personalized learning and allow for greater flexibility in education, moving away from traditional, teacher-centered models. In particular, in the context of higher education, technology in the classroom refers to the use of digital tools and online platforms to enhance teaching and learning, offering benefits such as increased engagement, diverse learning styles, and improved collaboration. It has moved beyond traditional methods to include e-learning and virtual classrooms. However, effective integration requires careful consideration of factors such as the teacher's role, potential distractions, and equitable access for all students (Mhlongo et al., 2023).

Technology-mediated learning offers new opportunities by enhancing engagement, personalizing the learning experience, and improving access to educational resources. It equips students with essential 21st-century skills, fosters collaboration across

geographical boundaries, and provides educators with data to inform their teaching practices. By using digital tools, students can learn at their own pace, explore complex topics through interactive methods, and develop critical thinking skills necessary for future careers (Ajayi, Ameh & Penda, 2025; Sunnasy & Heever, 2025). The study explores how technology-mediated learning, specifically synchronous (real-time) and asynchronous (self-paced) approaches, can be effectively integrated into the classroom to stimulate undergraduate intrinsic motivation and improve learning outcomes in the context of a general genetics course (BTC 214). It explores the crucial role of student intrinsic motivation in achieving meaningful learning outcomes, especially in the context of online or hybrid learning environments, with a focus on how the distinct characteristics of synchronous and asynchronous delivery influence students' interest, perceived competence, and overall success in mastering the general genetics concept (BTC 214).

General genetics (BTC 214), which is the primary focus of this study, is a foundational science course that requires active engagement and a deep understanding of complex biological concepts. A general genetics course outline typically covers

fundamental principles of heredity, from classical (Mendelian) genetics to molecular genetics. Key topics include Mendelian inheritance, gene linkage, DNA structure and function, gene expression, and population genetics. Practical exercises such as problem-solving, genetic analysis, and potentially laboratory work (e.g., electrophoresis and PCR) are common components. Learning general genetics is crucial for developing scientific literacy, enabling students to understand and participate in debates about modern genetics issues like genetic testing and gene technology. It provides essential knowledge for various careers in medicine, agriculture, public health, biotechnology, forensic science and research, and fosters critical thinking skills to contribute to societal progress, such as finding cures for genetic diseases or improving crops. Furthermore, it explains personal and family traits and diseases, improving personal understanding of health, while providing a foundation for understanding evolution and the diversity of life.

Despite the importance of general genetics to our industrial and daily activities, the researchers observe a consistent weakness among undergraduate students in general genetics in semester examinations, attributing it to difficulty in applying general genetics concepts to new contexts and in understanding gene expression mechanisms. Similarly, Paul (2023) highlighted that the challenges of learning general genetics include the abstract nature of concepts like DNA and genes, the complexity of interrelated ideas, and students' misconceptions. Other difficulties stem from teaching methods, such as insufficient time or poor explanations, as well as the ethical and emotional implications of genetic information, which can be a barrier to understanding. The importance of general genetics to daily life cannot be overemphasized. General genetics is vital to daily life because it helps us understand health and disease, improve agriculture, and develop new therapies. Thus, effective classroom teaching of general genetics should receive greater attention. Students' intrinsic motivation during classroom instructions has been reported to be very poor in Nigeria. The claim that Nigerian students' intrinsic motivation during classroom instruction is poor is supported by research pointing to several contributing factors, including large class sizes, poor teaching methods, and a lack of resources and funding, which can stifle student interest and engagement (Ajayi *et al.*, 2025; Niaz, 2002).

Sulaiman and Al-Shuaili (2025) concluded that poor teaching methods can cause low intrinsic motivation by undermining a student's sense of autonomy, competence, and relatedness. Teaching methods that lead to disengagement include over-reliance on extrinsic rewards like grades, a lack of student choice in learning activities, overly rigid or traditional approaches, and a failure to connect with students' interests. Conversely, effective teaching methods, such as offering choice, supporting autonomy, and fostering a positive learning environment, can enhance intrinsic motivation. Intrinsic motivation is doing an activity for the inherent satisfaction it provides, driven by internal factors like enjoyment, interest, and personal fulfillment, rather than external rewards or pressures (Di-Domenico & Ryan, 2017). Intrinsic motivation is a self-summoned willingness to learn. Those who are intrinsically motivated do not need sanctions or rewards to guide their efforts. Examples include reading a book because the story is fascinating or learning a new skill out of personal curiosity. Intrinsic motivation in learning is the internal drive to engage in an activity for its inherent satisfaction, such as curiosity or genuine interest. By implication, it is a powerful driver that enhances understanding and perseverance, and can be fostered by connecting general genetics to students' personal interests, fostering a sense of autonomy, and highlighting its perceived usefulness and the mastery of complex general genetics topics.

Ajayi (2019) concluded that students with low intrinsic motivation tend to avoid tasks they lack personal interest in, while those with high intrinsic motivation are more likely to engage in deeper learning and be more creative. This difference arises because high intrinsic motivation is driven by internal factors such as curiosity and personal satisfaction, leading to greater effort and higher-quality work. Conversely, low intrinsic motivation can lead to task avoidance, especially when facing

challenges or when disinterested in a new subject. Liu *et al.* (2023) noted that the modified lecture method (MLM) is popular in higher education due to its efficiency in large classes. However, it receives criticism for often being passive and teacher-centered, which can lead to poor engagement, low retention, and a lack of student-centered learning. Critics argue it does not foster creativity or critical thinking as effectively as more interactive methods, and can result in students being passive recipients rather than active participants. Thus, lecture-based learning may not always be the most effective for fostering intrinsic motivation, which is essential for long-term success. The increasing adoption of online and hybrid learning models presents new opportunities and challenges. It is unclear how the specific features of synchronous (e.g., live lectures, real-time discussions) and asynchronous (e.g., pre-recorded lectures, online forums) technology-mediated instruction affect a student's intrinsic motivation and, consequently, their learning outcomes. Learning outcomes are specific, measurable statements that describe the knowledge, skills, and values students should have after completing a general genetics course.

High intrinsic motivation may positively affect learning outcomes by fostering deeper understanding, greater persistence, increased creativity, and stronger information retention. Students who are intrinsically motivated are more likely to engage deeply with the material, use complex learning strategies, and develop stronger critical thinking skills because they are driven by genuine interest and the challenge of mastering a subject rather than by external rewards or pressures. Thus, developing lessons that enhance students' participation, interest, and persistence in a general genetics course are anticipated learning outcomes. Technology plays a large role in providing a more engaged learning environment, boosting collaboration, and supporting learning. Thus, the assertion calls for the need to find technology-mediated learning, specifically synchronous (real-time) and asynchronous (self-paced) approaches, that have the potential to develop students' critical thinking, problem-solving, and self-directed learning skills by providing access to vast information, fostering collaboration, and enabling personalized learning experiences. These approaches offer greater flexibility and engagement, leading to improved motivation and meaningful learning.

Synchronous learning approach (SLA) provides an opportunity for lecturers to connect in real time with their undergraduate students, even when separated by geographical distance. Synchronous online environments allow students and instructors to communicate via audio, video, text chat, an interactive whiteboard, application sharing, and instant polling, as if they were face-to-face in a classroom. Participants can talk, see each other via webcam, use emoticons, and work together in breakout rooms. An SLA is a real-time, live educational experience in which instructors and learners interact simultaneously, either in a physical classroom or online. This method relies on set schedules and includes activities like live webinars, virtual classes, and group video calls, which facilitate immediate feedback, dynamic communication, and a sense of community (Chen & Siau, 2016). In other words, a technology-mediated SLA involves real-time, instructor-led online instruction where all participants are online at the same time. It uses video conferencing platforms such as Zoom or Microsoft Teams for live lectures, discussions, and collaborative activities, enabling immediate feedback and interaction similar to a traditional classroom. This method facilitates dynamic communication and community building and can be effective for activities that require extensive discussion and collaboration. SL occurs when students and the instructor are together in "real time" but not at the "same place." SL is a specific type of online learning gaining importance for the convenience it offers both students and instructors while enhancing interactivity. Instructors and students are realizing the necessity of immediate interaction in their online experience, which is often referred to as "same time, some place learning." Adding synchronous components to online courses can enrich meaningful interaction among students and between students and instructors (Martin *et al.*, 2012).

An asynchronous learning approach (ALA) does not require real-time participation from the instructor and students, which can be supported through tools such as email, discussion boards, blogs, wikis, or video/audio recordings. ALA is a teaching methodology in which learning occurs independently, at different times and places. This approach is considered a practical learning experience for situations where real-time interaction is not required, such as practical skill development or risk-free practice scenarios (Motycka *et al.*, 2013). ALA often occurs in online learning environments, where instructors establish a learning path for students to engage with and progress through content at their own pace. Asynchronous courses frequently include recorded live sessions, making the content accessible for learners who cannot attend live. ALA modules typically involve reviewing didactic material through recordings, videos, or readings, as well as online interaction such as discussion forum posts or virtual office hours (Zingaro & Oztok, 2012). This research seeks to provide educators with valuable insights for designing and implementing effective technology-enhanced learning environments. The findings will help educators choose and implement technology-mediated learning strategies that best support student engagement and success in a general genetics course. This could lead to improved learning experiences and better learning outcomes for undergraduate students in public universities.

Objectives

The objectives of the study were to investigate whether technology-mediated SLA and ALA could reinforce undergraduate students' intrinsic motivation and learning outcomes in the context of general genetics (BTC 214). Specifically, the study:

1. Determine the effects of the SLA, ALA, and MLM on undergraduate students' intrinsic motivation in general genetics (BTC 214).
2. Ascertain the interaction effect of treatments and gender on undergraduate students' intrinsic motivation in general genetics (BTC 214).
3. Find out the effects of the SLA, ALA, and MLM on undergraduate students' learning outcomes in general genetics (BTC 214).
4. Ascertain the interaction effect of treatments and gender on undergraduate students' learning outcomes in general genetics (BTC 214).

Research Questions

The following research questions guided this study:

1. What is the mean intrinsic motivation ratings difference among undergraduate students taught general genetics (BTC 214) using SLA, ALA, and the MLM?
2. What is the interaction effect of treatments and gender on undergraduate students' intrinsic motivation rating in general genetics (BTC 214)?
3. What is the mean learning outcome scores difference among undergraduate students taught general genetics (BTC 214) using the SL approach, AL approach, and the MLM?
4. What is the interaction effect of treatments and gender on undergraduate students' learning outcome scores in general genetics (BTC 214)?

Hypotheses

The following null hypotheses guided the study:

1. There is no significant difference in the intrinsic motivation ratings of undergraduate students taught general genetics (BTC 214) using the SL, AL, or MLM.
2. There is no significant interaction effect of treatments and gender on the intrinsic motivation ratings of undergraduate students in general genetics (BTC 214).
3. There is no significant difference in the learning outcome scores of undergraduate students taught general genetics (BTC 214) using the SL, AL, or MLM.

4. There is no significant interaction effect of treatments and gender on the learning outcome scores of undergraduate students in general genetics (BTC 214).

Methodology

A quasi-experimental, non-randomized pretest-posttest control group design was employed. Participants were not randomly assigned individually but were allocated to treatment conditions as intact class groups to maintain ecological validity while acknowledging potential selection bias. The study used a convenience sample comprising the entire accessible population of 137 undergraduate students enrolled in Biology and Biology Education (200 level) at Federal University Lokoja. The study area is the Federal University of Lokoja, Kogi State, Nigeria. The Federal University Lokoja (FUL) was established in 2011 by the Federal Government of Nigeria. The FUL has two campuses: the main campus is located along the Lokoja-Okene expressway in Felele, Lokoja, while the College of Health Sciences is situated behind the Kogi State Specialist Hospital in Adankolo. This information describes the geographic location of the study area within Kogi State, Nigeria. The Federal University Lokoja is located between approximately 7°45' and 7°51' N latitude and 6°41' and 6°45' E longitude. The estimated student population for the FUL is over 17,000 as of June 2024, a significant increase from over 6,000 in 2021. This growth is attributed to the introduction of new faculties and academic programs, as well as the accreditation of all programs by the NUC (FUL, 2024). The target population of this study consists of 137 undergraduate students enrolled in the Biology and Biology Education courses at the 200 level for the 2024/2025 session at Federal University, Lokoja, Kogi State, Nigeria. There was no need for a sample size because the population size involved was small and easily accessible.

The Intrinsic Motivation Scale (IMS) and the General Genetics Learning Outcome Test (GGLOT) are the instruments used for data collection. IMS was a researcher-developed 25-item questionnaire intended to help undergraduate students express their level of intrinsic motivation for learning and solving problems related to general genetics (BTC 214) concepts. IMS is a 4-point Likert-scale rating with four response options. The options are very high extent (VHE), high extent (HE), low extent (LE), and very low extent (VLE). The GGLOT was a 50-question multiple-choice test designed to assess undergraduate students' learning outcomes and was drawn from general genetics course content.

The instructional lesson plans, IMS, and GGLOT were face- and content-validated by presenting them to three experts in Chemistry Education/Measurement and Evaluation. Upon validation, the reliability of the instruments was established by administering IMS and GGLOT to a random sample of 30 undergraduate students enrolled in the general genetics program at Prince Abubakar Audu University, Anyigba. After 2 weeks of 4 teaching periods, the IMS and GGLOT were administered. Cronbach's alpha was used to assess IMS reliability, yielding a coefficient of 0.89. The internal consistency of GGLOT (0.94) was assessed using the Kuder-Richardson (KR-21) formula. During the main study, the researcher trained three lecturers using synchronous learning (SL) lesson plans, asynchronous learning (AL) lesson plans, and Modified Lecture lesson plans, respectively, for 1 week. After the training, the students were randomly assigned to three groups: group A to experimental group 1 (SL approach group), group B to experimental group 2 (AL approach group), and group 3 to the Control group (Modified Lecture group).

Before actual teaching commenced, the IMS and GGLOT were administered as a pre-test by the Biology educators (lecturers), and this lasted for 1 period. During lessons, the biology educator taught the experimental group 1 general genetics (BTC 214) using an SLA lesson plan, the Biology educator taught the experimental group 2 general genetics (BTC 214) using an AL approach lesson plan, while the control group was taught the same general genetics (BTC 214) topics using a Modified Lecture lesson plan. The MLM combined traditional face-to-face lecturing with

periodic interactive questioning, brief discussions, and PowerPoint slides. It emphasized instructor explanations with limited student participation, unlike technology-mediated approaches that encouraged real-time or self-paced engagement. This lasted for 7 weeks. At the end of these actual teaching periods, the pre-test was reshuffled and administered as a post-test, which lasted for one week. The research questions were answered using *M* and *SD* scores, while the null hypotheses were tested using analysis of covariance.

Results

Research question one: What is the mean intrinsic motivation ratings difference among undergraduate students taught general genetics (BTC 214) using SLA, ALA, and the MLM?

Summary of the Pre-IMS, Post-IMS, and mean gain ratings for undergraduate students taught general genetics (BTC 214) using technology-mediated SLA, ALA, and MLM (Figure 1). The data in

Table 1 show that the gross mean difference between undergraduate students in SLA and MLM groups was 1.55 in favour of SLA. This implies that undergraduate students in the SL group had higher intrinsic motivation than those in the modified lecture group. Likewise, the overall mean difference between undergraduate students in the AL group and the MLM groups was 1.38 in favour of ALA. This implies that undergraduate students in the ALA group had higher intrinsic motivation than those in the modified lecture group. Compared with the overall mean difference of 0.15 between undergraduate students in the SLA and ALA groups.

Nevertheless, the slight difference favours SLA. This implies that undergraduate students in the SL group had slightly higher intrinsic motivation than their counterparts in the ALA group. In conclusion, undergraduate students taught using SLA had slightly higher intrinsic motivation than those taught using ALA. Meanwhile, undergraduate students taught general genetics (BTC 214) using ALA had a higher intrinsic motivation rating than those taught using MLM.

Table 1

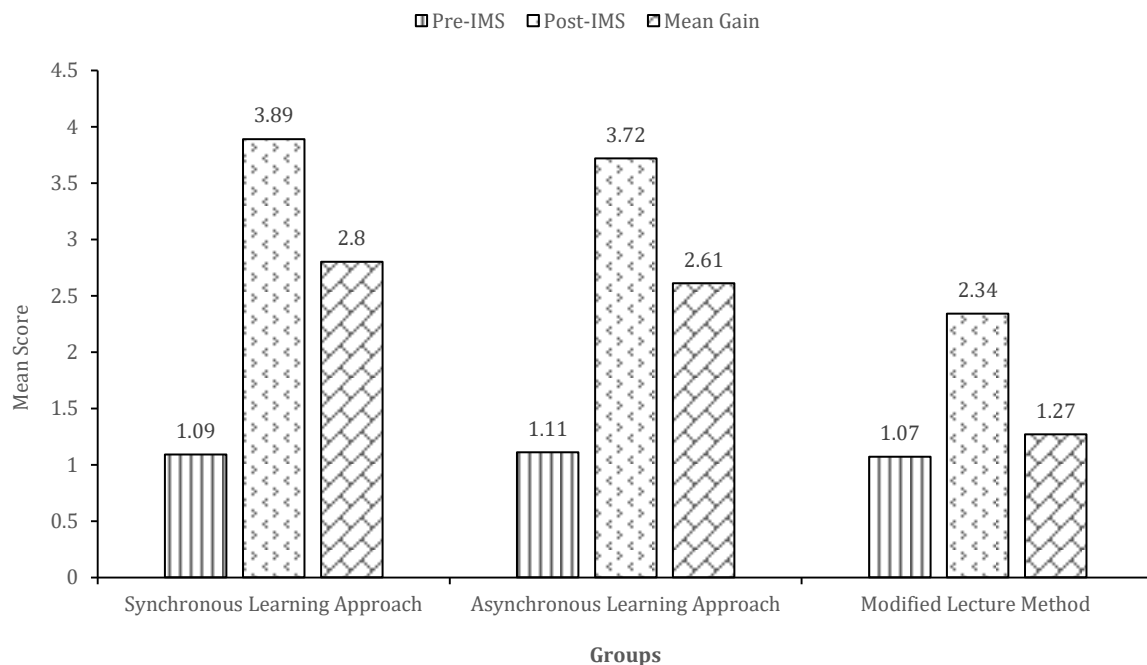
Mean Intrinsic Motivation and Standard Deviation Scores of Undergraduate Students Taught General Genetics (BTC 214) Using SLA, ALA, and MLM

Group	N	Pre-IMS (<i>M</i> ± <i>SD</i>)	Post-IMS (<i>M</i> ± <i>SD</i>)	Mean gain within group	Mean difference between groups (Post-Test Means)
SLA	47	1.09 ± 0.10	3.89 ± 0.35	2.80	—
MLM	49	1.07 ± 0.09	2.34 ± 0.21	1.27	1.55 (in favour of SL)
ALA	41	1.11 ± 0.12	3.72 ± 0.28	2.61	—
MLM	49	1.07 ± 0.09	2.34 ± 0.21	1.27	1.38 (in favour of AL)
SLA	47	1.09 ± 0.10	3.89 ± 0.35	2.80	—
ALA	41	1.11 ± 0.12	3.72 ± 0.28	2.61	0.15 (in favour of SL)

Note. Field experiments, 2025. IMS: intrinsic motivation scale.

Figure 1

Intrinsic Motivation (Pre-Test, Post-Test, and Mean Gain) Under SL, AL, and MLM Approaches



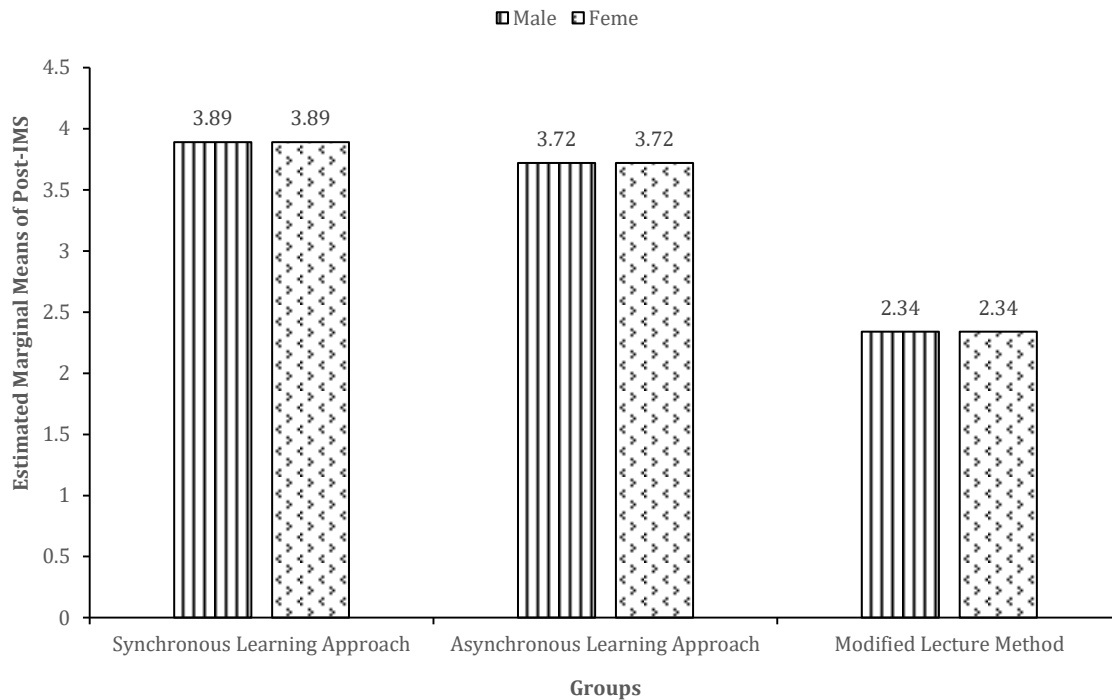
Research question two: What is the interaction effect of treatments and gender on undergraduate students' intrinsic motivation rating in general genetics (BTC 214)? Research question two is presented in Figure 2.

Figure 2 presents a bar chart of the interaction effect of treatments and gender on the mean intrinsic motivation rating of undergraduate students in general genetics (BTC 214). The bar charts of each treatment are roughly the same height for both

genders. In other words, it is concluded that the parallel lines connecting the tops of the bars in the graph indicate a minimal interaction effect between the treatment and gender on undergraduate students' intrinsic motivation in general genetics (BTC 214). This visual representation shows that the treatment's effect is consistent across both genders, meaning it has a similar impact on male and female students and does not differ significantly by gender.

Figure 2

Interaction Effect of Treatments and Gender on Undergraduate Students' Intrinsic Motivation in General Genetics (BTC 214)



Note. Covariate appearing in the modal are evaluated at the following value- Pre-IMS – 1.11.

Research question three: What is the mean learning outcome scores difference among undergraduate students taught general genetics (BTC 214) using the SLA, ALA, and MLM?

The summary of the Pre-GGLOT, Post-GGLOT, and mean gain scores of undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM (Figure 3). Table 2 presents the mean learning outcomes and standard deviation scores of undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM, on a paired-comparison basis. The data show that the gross mean difference between undergraduate students in SLA and MLM groups was 19.10 in commendation of SLA. This implies that undergraduate students in the SL group had higher learning outcomes than those in the modified lecture group. Similarly, the gross mean difference between undergraduate

students in the AL group and the MLM groups was 12.90, in accordance with ALA. This suggests that undergraduate students in the ALA group had higher learning outcomes than those in the modified lecture group. Similarly, the gross mean difference between undergraduate students in SLA and ALA groups was 6.20. However, the minor difference favours SLA. This implies that undergraduate students in the SL group achieved slightly higher learning outcomes than those in the ALA group. In conclusion, undergraduate students taught using the SLA had slightly higher learning outcomes than those taught using the ALA. Meanwhile, undergraduate students taught general genetics (BTC 214) using the ALA had higher learning outcomes than those taught using MLM.

Table 2

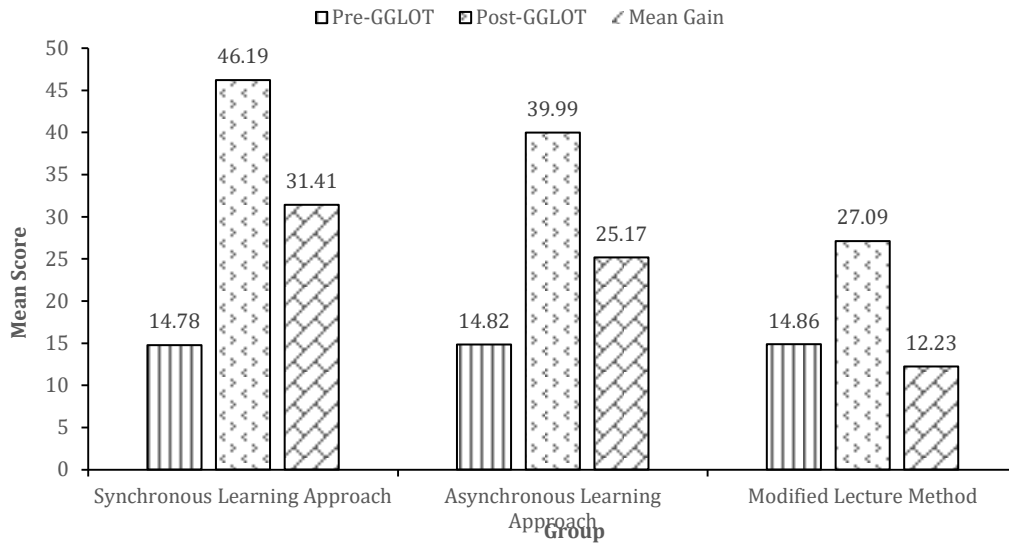
Comparative Learning Outcome Scores (Pre-GGLOT, Post-GGLOT, and Gain) of Students Taught Using SLA, ALA, and MLM

Group	N	Pre-GGLOT (M ± SD)	Post-GGLOT (M ± SD)	Mean gain (Within group)	Mean Difference (Between Groups) (Post-test Means)
SLA	47	14.78 ± 3.02	46.19 ± 5.18	31.41	—
MLM	49	14.86 ± 3.11	27.09 ± 4.03	12.23	19.10 (in favour of SL)
ALA	41	14.82 ± 3.13	39.99 ± 3.29	25.17	—
MLM	49	14.86 ± 3.11	27.09 ± 4.03	12.23	12.90 (in favour of AL)
SLA	47	14.78 ± 3.02	46.19 ± 5.18	31.41	—
ALA	41	14.82 ± 3.13	39.99 ± 3.29	25.17	6.20 (in favour of SL)

Note. Field experiments, 2025. GGLOT: General Genetics Learning Outcome Test.

Figure 3

Pre-GGLOT, Post-GGLOT, and Mean Gain in effect of SLA, ALA, and MLM on Undergraduate Students' Learning Outcomes in General Genetics (BTC 214)

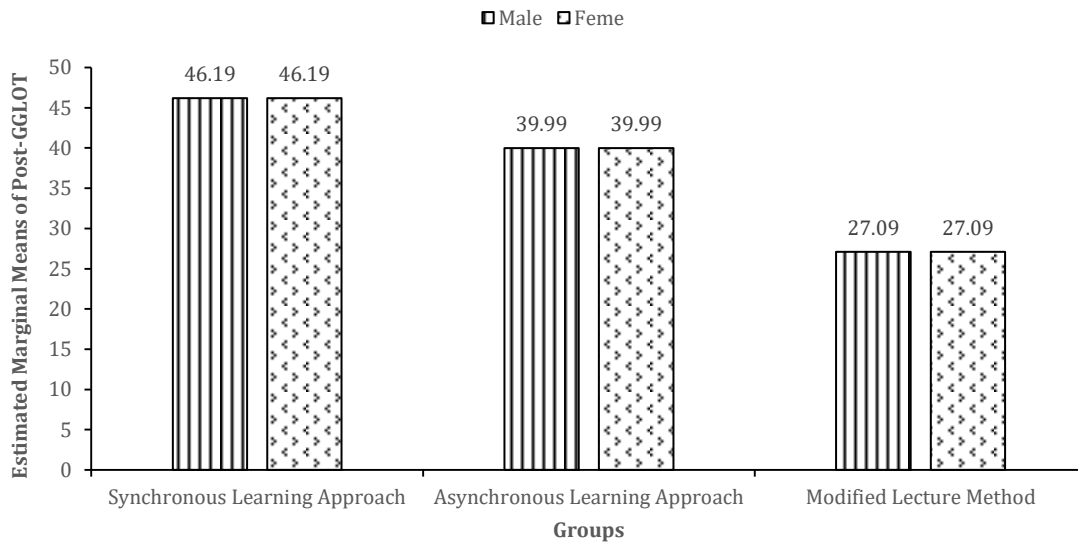


Research question four: What is the interaction effect of treatments and gender on undergraduate students' learning outcome scores in general genetics (BTC 214)? Figure 4 shows the interaction effect of treatments and gender on the mean learning outcome scores of undergraduate students in general genetics (BTC 214). The bar charts of each treatment are roughly the same height

for both genders. In other words, it interprets the bar chart in which the lines connecting the tops of the bars are nearly parallel, indicating that the effects of the different treatments were similar for both males and females. This suggests a very small or insignificant interaction effect between treatment and gender on students' learning outcomes in general genetics (BTC 214).

Figure 4

Interaction Effect of Treatments and Gender on Undergraduate Students' Learning Outcome in General Genetics (BTC 214)



Note. Covariate appearing in the modal are evaluated at the following value- Pre-GGLOT - 14.17.

Hypothesis one: There is no significant difference in the intrinsic motivation ratings of undergraduate students taught general genetics (BTC 214) using the SLA, ALA, and MLM.

Table 3 presents the two-way ANCOVA result for the mean intrinsic motivation rating of undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM. The data in Table 3 reveal that the observed mean difference in the intrinsic motivation rating among the groups was significant [$F(2, 130) = 95.06, p < .05$]. Hence, the null hypothesis that there is no significant difference in the mean intrinsic motivation ratings of

undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM was rejected. This suggests a significant difference in the mean intrinsic motivation scores across the groups. Meanwhile, the effect size was 0.59, as indicated by the corresponding partial eta-squared value, which is considered a large effect size. This implies that 59.40% of the difference or variance in the intrinsic motivation ratings among the groups was explained by the treatments. Thus, the difference in the intrinsic motivation rating among the groups has a large statistical effect size.

Table 3

Two-Way ANCOVA for Mean Intrinsic Motivation Rating of Undergraduate Students Taught General Genetics (BTC 214) using SLA, ALA, and MLM

Source	Type III sum of squares	df	MS	F	p	Partial eta squared
Corrected model	62.974 ^a	6	10.496	39.026	0.000	0.643
Intercept	4.211	1	4.211	15.656	0.000	0.107
TP _r ^{HMS}	1.037	1	1.037	3.857	0.052	0.029
Group	51.133	2	25.567	95.064	0.000	0.594
Gender	0.003	1	0.003	0.012	0.914	0.000
Group*Gender	0.008	2	0.004	0.015	0.986	0.000
Error	34.963	130	0.269			
Total	1407.942	137				
Corrected total	97.936	136				

Note. R squared = .643 (Adjusted R Squared= .627).

Table 4 shows Bonferroni post hoc multiple comparisons for the mean intrinsic motivation ratings of undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM. The results indicate that the mean difference between SLA and MLM is 1.5430* and this is significant at $p < .05$. This implies that there is a significant difference in the mean intrinsic motivation ratings between the undergraduate students taught general genetics (BTC 214) using and those taught using MLM in comparison with undergraduate students in SLA class. Likewise, the results reveal that the mean difference (I-) between ALA and MLM is 1.1622*

and this is significant at $p < .05$. This implies that there is a significant difference in the mean intrinsic motivation ratings between the undergraduate students taught general genetics (BTC 214) using ALA and those taught using MLM in comparison of the undergraduate students in ALA class. However, the paired comparison of ALA and SLA showed a mean difference of -0.3808, which is not significant at $p > .05$. This suggests no significant difference in the mean intrinsic motivation ratings between undergraduate students taught using the SL and AL instructional approaches.

Table 4

Bonferroni Post Hoc Multiple Comparisons for Mean Intrinsic Motivation Ratings of Undergraduate Students' Taught General genetics (BTC 214) using SLA, ALA, and MLM

Group comparison	MD	SE	*p*	95% CI
Synchronous vs. Modified lecture	1.543	0.106	< .001	[1.286, 1.800]
Asynchronous vs. Modified lecture	1.162	0.110	< .001	[0.896, 1.428]
Asynchronous vs. Synchronous	-0.381	0.111	.102	[-0.650, -0.112]

Note. MD = mean difference, CI = confidence interval.

Hypothesis two: There is no significant interaction effect of treatments and gender on the intrinsic motivation ratings of undergraduate students in general genetics (BTC 214).

The table presents a two-way ANCOVA for intrinsic motivation among undergraduate students enrolled in general genetics (BTC 214) taught using the SLA, ALA, and MLM. The table presents the interaction effect of instructional strategies and gender. The data in Table 3 suggest that there is no significant interaction between treatment and gender on the mean intrinsic motivation ratings of undergraduate students in general genetics (BTC 214) [$F(2, 130) = 0.015, p > .05$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.001, as indicated by the partial eta-squared value, which is considered a small effect. This implies that only 0.1% of the interaction in the intrinsic motivation rating among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on undergraduate students' intrinsic motivation has a small statistical effect size.

Hypothesis three: There is no significant difference in the learning outcome scores of undergraduate students taught general genetics (BTC 214) using the SLA, ALA, and MLM.

The data in Table 5 reveal that the observed mean difference in learning outcome scores among the groups was significant [$F(2, 130) = 104.994, p < .05$]. Hence, the null hypothesis that there is no significant difference in the mean learning outcome scores of undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM was rejected. This implies a significant difference in the mean learning outcome scores across the groups. Meanwhile, the effect size was 0.618, as indicated by the partial eta-squared, which is considered a large effect. This implies that the treatments accounted for 61.8% of the difference in learning outcome scores across the groups. Hence, the difference in the learning outcome scores among the groups has a large statistical effect size.

Table 5

Two-Way ANCOVA for Learning Outcome Scores of Undergraduate Students Taught General Genetics (BTC 214) using SLA, ALA, and MLM

Source	Type III SS	df	MS	F	*p*	Partial η^2
Corrected Model	6403.166	6	1067.194	39.664	< .00	.647
Intercept	683.671	1	683.671	25.410	< .00	.164
Pretest (GGLOT)	32.404	1	32.404	1.204	.27	.009

Group	Sum of Squares	df	Mean Square	F	p	Partial η^2
Group	5649.933	2	2824.966	104.99	< .00	.618
Gender	32.993	1	32.993	1.226	.27	.009
Group × Gender	67.627	2	33.813	1.257	.28	.019
Error	3497.768	13	269.060			
Total	168477.00	137				
Corrected Total	9900.934	136				

Note. $R^2 = .647$ (Adjusted $R^2 = .630$). GGLOT = General Genetics Learning Outcome Test.

Table 6 presents Bonferroni post hoc multiple comparisons of the mean learning outcome scores for undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLA. The results reveal that the mean difference (I-J) between SLA and MLM is 16.126 and this is significant at $p < .05$. This implies that there is a significant difference in the mean learning outcome scores between the undergraduate students taught general genetics (BTC 214) using SLA and those taught using MLM in comparison with undergraduate students in SLA class. Likewise, the results reveal that the mean difference between AL approach

and MLM is 6.819 and this is significant at $p < .05$. This implies that there is a significant difference in the mean learning outcome scores between the undergraduate students taught general genetics (BTC 214) using ALA and those taught using MLM in commendation of undergraduate students in ALA class. However, the paired comparison of ALA and SLA showed a mean difference of -9.306 and was significant at $p < .05$. This indicates a significant difference in the mean learning outcome scores between undergraduate students taught using technology-mediated SL and AL instructional approaches.

Table 6

Bonferroni Post Hoc Comparison for Mean Learning Outcome Scores of Undergraduate students' Taught General Genetics (BTC 214) using SLA, ALA, and MLM

Group comparison	MD	SE	* p *	95% CI
Synchronous vs. Modified lecture	16.126	1.063	< .001	[13.549, 18.702]
Asynchronous vs. Modified lecture	6.819	1.102	< .001	[4.149, 9.490]
Asynchronous vs. Synchronous	-9.306	1.112	< .001	[-12.003, -6.610]

Note. MD = mean difference, CI = confidence interval.

Hypothesis four: There is no significant interaction effect of treatments and gender on the learning outcome scores of undergraduate students in general genetics (BTC 214).

The table presents the interaction effect of instructional strategies and gender. The data reveal no significant interaction between treatment and gender on the mean learning outcome scores of undergraduate students in general genetics (BTC 214) [$F(2, 136) = 1.257, p > .05$]. The null hypothesis is therefore not rejected. Meanwhile, the effect size was 0.019, as indicated by the partial eta-squared, which is considered a small effect. This implies that only 1.9% of the interaction in the learning outcome scores among groups was explained by treatments and gender. Hence, the interaction of treatments and gender on undergraduate students' learning outcome scores has a small statistical effect size.

Discussion

The study investigated whether technology-mediated pedagogies, such as SLA and ALA, could reinforce undergraduate students' intrinsic motivation and learning outcomes in the context of general genetics (BTC 214) at Federal University Lokoja, Kogi State, Nigeria. The findings of this study suggested that the difference in the intrinsic motivation rating among undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLM was statistically significant. The post hoc multiple comparisons of the intrinsic motivation ratings among the groups indicated that undergraduate students taught general genetics (BTC 214) using SLA had higher intrinsic motivation than those taught using the modified lecture method. This is in line with Martínez-Huamán et al. (2023), who conclude that teaching through chunking in synchronous classes influences the intrinsic motivation of university students, consolidates their learning, and improves teachers' pedagogical practices more than the conventional method. Likewise, this is in line with Ajayi, Ameh, and Alabi (2025). Findings indicate that undergraduate students' self-confidence and critical thinking abilities were significantly enhanced when taught using technology-assisted constructivist approaches, compared to their counterparts taught using conventional approaches. The likely explanation for this outcome may be that SLA fosters real-time interaction, immediate feedback, and a stronger sense of community among learners. This live, scheduled interaction provides structure, increases engagement, and enables collaborative problem-solving, which can enhance undergraduate students' intrinsic motivation compared to the modified lecture method. Thus, SLA has a generally positive effect on students' intrinsic motivation, primarily by facilitating social interaction and providing immediate feedback.

The post hoc multiple comparisons of the intrinsic motivation ratings among the groups indicated that undergraduate students

taught general genetics (BTC 214) using ALA had significantly higher intrinsic motivation than those taught using the modified lecture method. This finding agrees with Aque et al. (2021), who found that asynchronous learning effectively enhances students' motivation in science compared with the conventional teaching approach. Similarly, a study by Nsikak-Abasi and Udeme (2021) found that students who learnt through the asynchronous instructional approach were better motivated and scored higher in advanced educational research than students who learnt through the lecture method. In conclusion, asynchronous learning can positively affect students' intrinsic motivation by increasing flexibility and autonomy, allowing them to learn at their own pace and schedule, thereby reducing anxiety and improving engagement. This suggests that ALA can improve students' intrinsic motivation by offering flexibility, allowing them to learn at their own pace, and reducing social barriers, thereby promoting deeper engagement with the material. This independence fosters better time management and helps students balance their lives with their studies, leading to increased self-efficacy and greater motivation to learn. The post hoc comparison of the intrinsic motivation ratings among the groups further revealed that the difference between undergraduate students taught general genetics (BTC 214) using the SLA and those taught using the ALA was not statistically significant. Hashim et al. (2023) found a higher level of students' engagement and learning motivation in synchronous and asynchronous open distance learning (ODL) activities. However, the likely explanation for this outcome is that both synchronous and asynchronous learning are important for fostering intrinsic motivation. However, they do so through different mechanisms, based on the three core psychological needs identified in self-determination theory: autonomy, competence, and relatedness. Synchronous learning excels at building a sense of community and providing instant feedback, while asynchronous learning promotes autonomy and reflective engagement.

The findings of this study revealed that the difference in the learning outcome scores among undergraduate students taught general genetics (BTC 214) using SLA, ALA, and MLA was statistically significant. The post hoc multiple comparisons of the learning outcome scores among the groups revealed that undergraduate students taught general genetics (BTC 214) using the SL approach had significantly higher learning outcomes than their counterparts taught using the modified lecture method. This aligns with Prudente (2023), who concluded that it can be inferred that the synchronous learning approach is a more effective strategy for improving grade 3 learners' academic performance than the traditional method. This finding contradicts those of Eminue et al. (2023), who found that students taught accounting using a traditional (face-to-face) method performed better than those taught using synchronous (video conferencing or virtual classroom) instructional strategies. In another related

study, this finding agrees with Secreto and Tabo (2023), who concluded that synchronous online attendance positively impacts students' academic performance compared to the lecture teaching method. By implication, the effect of a synchronous learning approach on undergraduate students' learning outcomes is largely positive, as it is associated with higher final grades, better engagement, and increased student satisfaction through real-time interaction, peer feedback, and a greater sense of community. However, performance can depend on the student's ability to attend live sessions and remain engaged, and the quality of the course design, such as the inclusion of active learning strategies and support materials, can also influence learning outcomes compared to the modified lecture method.

The post hoc multiple comparisons of the learning outcome scores among the groups also revealed that undergraduate students taught general genetics (BTC 214) using ALA had significantly higher learning outcomes than those taught using MLM. This finding agrees with that of Qamar et al. (2025), who found that students in the asynchronous group outperformed those in the discussion group. In conclusion, asynchronous learning can lead to better academic performance compared to a modified lecture method due to its self-paced nature, flexibility, and increased cognitive engagement. Asynchronous environments demonstrate significantly better performance because they allow students more time to focus, process information, and develop critical thinking skills. The flexibility to access materials at any time and from any location also accommodates diverse learning styles and time commitments, potentially reducing anxiety and improving overall engagement. The modified lecture method is often more direct for knowledge transfer. However, asynchronous learning's flexibility allows students more time to process information, explore different perspectives, and access materials at their own convenience.

The post-hoc comparison of the learning outcome scores among the groups further revealed that the difference between undergraduate students taught general genetics (BTC 214) using the SL approach and those taught using the AL approach was statistically significant. This finding agrees with Chafouk and Marjanei (2024), who reported that the synchronous group showed higher engagement and a greater positive impact of interaction on understanding than the asynchronous group. Similarly, Lowe (2024) concluded that synchronous learning enhances motivation and understanding of complex topics more than asynchronous learning. In conclusion, synchronous learning can positively impact students' academic performance by increasing engagement and providing immediate feedback, leading to higher achievement and satisfaction than asynchronous learning. However, its effectiveness depends on factors such as active participation; students who regularly attend live classes generally achieve higher grades. A balanced approach that integrates both synchronous and asynchronous elements is recommended to cater to diverse student needs and support different aspects of learning. A synchronous learning approach can enhance collaboration, motivation, and academic achievement while also reducing feelings of isolation. However, it is less flexible than asynchronous learning due to fixed schedules, which may pose challenges for some students.

The study's findings revealed that the interaction effect between approach and gender is minimal but not statistically significant, suggests that neither approach nor gender significantly alters the outcome for the other. This means that, overall, the effect of the learning approach on intrinsic motivation and learning outcomes is similar for both male and female students, and gender does not modify the approach's effectiveness. The ANCOVA test confirms the lack of a statistically significant interaction effect at the .05 level of significance. This indicates that, in general genetics (BTC 214), neither students' learning strategies nor their gender affected their intrinsic motivation or how well they performed. This means that the impact of different teaching approaches on motivation and learning outcomes was the same for both male and female students in this particular case. Hence, either technology-mediated pedagogies, such as SLA or ALA, can be successfully used to foster undergraduate students' intrinsic motivation and

learning outcomes, irrespective of gender. In this case, there is no need to separate the instructional approach for male and female undergraduate students, since either the SLA or ALA could be used successfully across the three groups.

Conclusion

This study found that technology-mediated synchronous (SL) and asynchronous (AL) learning approaches improved students' intrinsic motivation and learning outcomes in General Genetics more effectively than the modified lecture method (MLM). While both SL and AL significantly enhanced motivation compared to MLM, no significant difference was found between them. For learning outcomes, however, both approaches outperformed MLM, and SL produced significantly higher achievement than AL. Overall, the results highlight the value of technology-mediated instruction, with synchronous learning offering the strongest benefit for academic performance.

Recommendations

From the findings of this study, the following recommendations were made:

1. Lecturers should be encouraged to employ the use of SL and AL approaches in order to elevate undergraduate students' intrinsic motivation and learning outcomes in the context of general genetics (BTC 214);
2. The university administrators and lecturers of Nigerian universities should implement capacity-building programs to train their lecturers and students in the use of technology-mediated pedagogies, such as SL and AL approaches, as these improve undergraduate students' intrinsic motivation and learning outcomes.
3. The National Universities Commission should develop the appropriate frameworks to encourage the adoption of technology-mediated pedagogies, such as SL and AL approaches, in Nigerian universities for effective teaching and learning.

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