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Effects of Technology-Enhanced Learning on Higher Secondary Students' Cognitive, Behavioral, and Emotional Engagement in Multiple Subjects

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ABSTRACT
This study examined how higher secondary students in the Arts, Science, and Commerce streams were affected cognitively, behaviorally, and emotionally by technology-enhanced learning (TEL). A sample of 389 students chosen by stratified random sampling was used in a quantitative, descriptive-cum-comparative design. One-Way ANOVA and post hoc tests were used to analyze the data, which were gathered using a standardized engagement questionnaire. The findings showed that students' levels of cognitive and behavioral engagement varied significantly, with Arts students showing lower levels than Science and Commerce students. While there was no discernible difference between Arts and Science, Commerce students had the highest emotional engagement, greatly outperforming both. Results indicate that the effectiveness of TEL varies by subject and is impacted by student digital literacy, instructional design, and content type. In order to maximize engagement across all streams and guarantee fair and significant learning experiences in higher secondary education, the study suggests customized TEL interventions, pedagogical alignment, and teacher training.

Keywords: *Technology-Enhanced Learning, Student Engagement, Cognitive, Behavioral, Emotional.*

Introduction

Technology enhanced learning (TEL) has become an essential source of instructional innovation and pedagogic change in the ever-changing education landscape of the twenty first century. In the higher secondary level, students are supposed to have a lot of involvement with more complicated material in their subject areas not only in mathematics and the sciences, the languages and social studies, but also beyond mere memory learning to thinking critically, working in groups, and taking on longer term work. It is on this background that TEL, deliberate integration of digital equipment like interactive environments, multimedia, virtual simulations, mobile learning, and online collaborative settings, have been placed as a method to improve academic interaction and academic achievement (Rotar, 2025; Ibrahim et al., 2025; Diwan, 2025).

Student engagement is a concept that is generally accepted to be multidimensional in nature and comprises cognitive, behavioral, and emotional engagement. The concept of cognitive engagement means mental investment in studying, such as deep thinking, self control, and planning (Fredricks et al., 2004). Observable behaviors include attention, participation, persistence and time on task, which are behavioral engagements (Fredricks et al., 2004). Emotional engagement captures emotional response of learning activities such as interest, enjoyment and importance attached to academic activities (Fredricks et al., 2004). It is always

revealed that high scores on these dimensions are correlated with increased retention, academic achievement, and long term learning according to research (Rotar, 2025; Diwan, 2025).

The engagement is even more salient in the technological contexts. TEL tools have the ability to offer interactive, personalized, and learner centered experiences that the traditional pedagogies tend to be deficient in. As an example, interactive simulations and visualizations would enable the learners to investigate abstract concepts, thus provoking the cognitive work (Rotar, 2025; Ibrahim et al., 2025). Students have been connected with collaboration systems and discussion forums, which are some of the pillars of behavioral engagement (Rotar, 2025; Diwan, 2025). In the meantime, emotional reactions of students to learning may be affected by the use of multimedia, feedback personalization, gamification, and adaptation tools as it will make the learning activities more engaging and relatable (Shao et al., 2025; Rotar, 2025; Diwan, 2025).

Although TEL promise is there, studies highlight that technology is not necessarily effective in terms of engagement. The TEL implementation needs to be based on close pedagogical alignment, preparation of teachers, and infrastructure support (Rotar, 2025; Ibrahim et al., 2025). Research on the secondary education proves that unsustainable technology integration can even distract the learners and decrease the engagement in case of improper alignment to the curricular purpose or the lack of appropriate training of the educators (Kearney, 2020; Rotar, 2025). The reason is that, therefore, the possibility to learn how TEL can influence cognitive, behavioral, and emotional involvement, particularly in the context of several courses in higher secondary schools, is timely and essential.

Furthermore, although some studies have been conducted on engagement in either primary or higher education environment, very little is known regarding the impact of TEL on engagement in the critical phase of higher secondary schooling. This grade level is a transition between basic understanding and the advanced thinking to academic and career-related choices and therefore student interaction is crucial in determining the results of learning. The current research paper attempts to fill this gap by methodically analyzing the effect of technology enhanced learning on the three dimensions of engagement of higher secondary students in different subjects.

In this way, the research addresses a developing literature that indicates that TEL has been capable of offering differentiated learning opportunities, real-time feedback, and cooperative learning that has enriched the learning experience (Rotar, 2025; Ibrahim et al., 2025). Meanwhile, it recognizes the subtle combination of pedagogical, emotional, and behavioral elements that determine the way students use technology in school. It is hoped that the findings will provide some of the insights that can be used by policymakers, educators, and curriculum designers in order to utilize the opportunities offered by TEL to the fullest so that it could contribute to meaningful engagement and positive academic achievements in secondary schools.

Literature Review

Student Engagement

Student engagement is a combination of cognitive, behavioral, and emotional aspects that altogether forebode academic performance. Fredricks, Blumenfeld, and Paris (2004) conceptualized the concept of engagement as a complex construct that connects the classroom activities and student learning outcomes. Cognitive learning entails intensive processing and utilization of elaborate learning methods, e.g., critical thinking and problem solving. Behavioral engagement involves engagement, perseverance and adherence to academic standards.

Emotional engagement involves interest of students in learning tasks, enjoyment and emotional reaction to learning tasks of students.

Studies show that engagement dimensions are dynamically interactive. There is a tendency of emotional involvement leading to more behavioral involvement and cognitive effort whereas cognitive interest may support emotional interest by leading to achievement and mastery. Thus, it is important to analyze the engagement as a whole in measuring the impact of educational innovations such as TEL (Fredricks et al., 2004; Passyn, 2023).

Technology Enhanced Learning

Technology Enhanced Learning (TEL) is the willful inclusion of online tools namely learning management systems (LMS) and mobile applications, simulation software, and interactive environments to supplement and enhance learning. TEL is similar to constructivist and socio-cultural theories of learning that focus on active construction of knowledge, collaboration and solving of problems in context. There is some evidence that may indicate that TEL is potentially useful to create self-directed learning, instant feedback and interaction that are essential to engage (Rotar, 2025; Ibrahim et al., 2025).

According to the recent review of 50 empirical studies conducted by Rotar (2025), theoretically informed TEL implementation, which extends beyond the technological access, is necessary. In particular, Rotar observes that TEL research tends to pay disproportionate attention to behavioral engagement (e.g., the frequency of participation) and little to no attention to cognitive and emotional aspects. Such an imbalance implies that technology should be incorporated in a strategic manner with a definite pedagogical purpose to influence various aspects of engagement.

TEL and Cognitive Engagement

The TEL environments are the ones characterized by the long-term intellectual investment and cognitive resources strategic utilization. Virtual laboratory, simulation, adaptive learning environment that are part of TEL tools have proven to be helpful in complex problem solving and conceptual learning because learners are allowed to experiment and control variables. The tools assist the students in moving beyond the surface of learning and participate in deep processing, hypothesis testing, and reflection.

As an illustration, higher education studies have established that TELs that constitute engagement on emotional, cognitive, and behavioral levels enhanced academic achievement when cognitive engagement is put first among other aspects (ScienceDirect article on TEL engagement, 2025). Similarly, technologies that provide personal feedback have also been associated with higher levels of cognitive engagement since they allow students to self monitor and control their learning strategies (ScienceDirect article, 2025). This kind of research brings out the aspect of TEL that can contribute a deeper thinking especially in a situation where the use of technology is incorporated in inquiry based learning designs.

TEL and Engagement in Behavior

Behavioral engagement is the behavior which can be observed by the students and which represents the involvement in learning. The behavioral engagement can be encouraged through TEL since it provides interactive and collaborative platforms that contribute to active participation. Digital forums, real time quizzes, gamified learning exercises, and mobile response systems are some examples of tools that can make students more engaged and determined in something.

The research study based on high school students revealed that digital learning platforms played an important role in behavioral engagement, and greater participation and task completion were effective when students were able to apply interactive technologies (Diwan,

2025). Equally, the use of collaborative online tools has been linked to higher levels of interactions when compared to those who do not utilize the tools to interact with peers, a factor that enhances desire to attend and work on learning activities. However, the studies also warn that TEL can turn into a distractor instead of an engagement mechanism unless there is a proper pedagogical guideline, and thus, teacher facilitation and a well-organized use of technology will be necessary (Kearney, 2020).

TEL and Affective Involvement

Emotional engagement is the part of learning that involves the affective part of the students feelings, attitude and the emotional response of the students towards learning activities. TEL can be used to improve emotional experience with immersive multimedia, personalized feedback and content. Interactive and visual elements may cause interests and pleasure, resulting in increased receptiveness and motivation.

A pre experimental study in the higher education settings established that affective engagement rate rose significantly following the incorporation of technology based learning relative to the conventional approaches, and visual and multimedia qualities specifically exhibited as a contributor to positive emotional responses (Surlitasari et al., 2023). In the same way, high emotional engagement has been associated with the use of LMS and social networking tools in the courses particularly where the students develop a sense of community and belonging in the use of such tools (Teng and Wang, 2021).

Nevertheless, studies also indicate that the emotional facilitation of TEL is not automatic. The novelty effect - the preliminarily enthusiasm regarding new tools might momentarily improve engagement upon exclusion of the technology to help significant learning (Novelty effect research, 2024). Thus, the concept of sustainability of the emotional engagement relies on the fact that the technology is embedded in the well designed experiences of instruction as opposed to the availability of the technology.

Even though studies on the effects of TEL are extensive in individual subjects, there is limited research on its effects among various subjects in the secondary level. However, there is also some evidence that interactive and collaborative technologies can be used to facilitate interaction in math, language arts, and science courses by making abstract concepts more understandable and the learning experience more meaningful. Such examples are digital learning tools that enable the use of simulation and visualization in science, which can support experiential learning; as well as language learning tools that include interactive elements, which support practice and feedback in language courses (Ibrahim et al., 2025). These results indicate that the advantages of TEL could be widespread in subject areas in case of adaptation to disciplinary learning objectives.

Research Objectives

1. To investigate how technology-enhanced learning (TEL) affects higher secondary students' cognitive engagement in a variety of subjects.
2. To look into how technology-enhanced learning (TEL) affects higher secondary students' behavioral engagement in a variety of subjects.
3. To examine how technology-enhanced learning (TEL) affects higher secondary students' emotional engagement in a variety of subjects.

Null Hypotheses (H_o)

H_{o1}: Technology-enhanced learning does not significantly alter students' cognitive engagement in a variety of subjects at the upper secondary level.

H_{o2}: Technology-enhanced learning does not significantly alter students' behavioral engagement in a variety of subjects at the upper secondary level.

H_{03}: Technology-enhanced learning does not significantly alter students' emotional engagement in a variety of subjects at the upper secondary level.

Methodology

In order to investigate the effects of technology-enhanced learning (TEL) on students' cognitive, behavioral, and emotional engagement in a variety of higher secondary subjects, this study used a quantitative, descriptive-cum-comparative research design. Students enrolled in the Arts, Science, and Commerce streams made up the population. Stratified random sampling was used to choose a sample of 389 students in order to guarantee proportionate representation across subjects. A standardized engagement questionnaire measuring cognitive, behavioral, and emotional aspects was used to gather data. One-Way ANOVA was used in the statistical analyses to compare engagement across streams, and post hoc tests were used to find pairwise differences. The study complied with ethical standards, guaranteeing voluntary participation, informed consent, and anonymity. SPSS 26 was used to analyze the data.

Table 1

Impact of Technology-Enhanced Learning on Students' Cognitive Engagement Across Multiple Subjects at the Higher Secondary Level (One Way ANOVA)

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.340	2	2.170	7.725	.001**
Within Groups	108.421	386	.281		
Total	112.761	388			

Note: **p < .01

The findings of Table 1 of the One-Way ANOVA test the effect of technology-enhanced learning (TEL) on cognitive engagement of students in Arts, Science and Commerce stream in the higher secondary level. The between groups variance (S 2 = 4.340, df = 2) was compared to the within groups variance, (S 2 = 108.421, df = 386) that yielded an F-value of 7.725 that had a significance level of.001, which is lower than the 0.01 level. This shows that there is a significant difference in cognitive engagement among the students in the divergent subject streams that are statistically significant. Thus, the null hypothesis Ho1 which believes that there is no significant differences in cognitive engagement as a result of TEL is rejected. The implications of this are that technology-enhanced learning has a different impact in subject streams, indicating the difference in the effectiveness of TEL interventions in order to stimulate deep thinking and strategic learning behaviors in Arts, Science, and Commerce students.

Table 2

Impact of Technology-Enhanced Learning on Students' Cognitive Engagement Across Multiple Subjects at the Higher Secondary Level (Post Hoc Analysis)

Comparison	Mean Difference	Std. Error	Sig.	Interpretation
Arts vs Science	−0.309	0.090	.002	Significant
Arts vs Commerce	−0.378	0.097	.000	Significant
Science vs Commerce	−0.068	0.062	.510	Not significant

Table 2 is the post hoc pair wise comparisons of cognitive engagement of students in Arts, Science and Commerce streams after significant One-Way ANOVA. Comparison of Arts and Science reveals a mean difference of -0.309 (p =.002) and Arts and Commerce reveals a mean difference of -0.378 (p =.000), both are statistically significant at 0.01 level. This implies that Arts students show a much lower cognitive involvement in technology-enhanced learning in comparison to the students of Science and Commerce. However, the difference between the two streams is not significant because the comparison between Science and Commerce (mean difference = -0.068, p =.510) is less significant. These findings suggest that TEL has quite

different effects on cognitive engagement depending on the subject with Arts students having less than Science and Commerce students.

Table 3

Impact of Technology-Enhanced Learning on Students' Behavioral Engagement Across Multiple Subjects at the Higher Secondary Level (One Way ANOVA)

Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.380	2	1.690	6.416	.002**
Within Groups	101.668	386	.263		
Total	105.048	388			

Note: **p < .01

Table 3 shows findings of a One-Way ANOVA on the differences in behavioral engagement of students studying Arts, Science, and Commerce streams in technology-enhanced learning (TEL). The F-value 6.416 with the significance level of p =.002 (less than the 0.01 value) was developed by the between-groups variance (Mean Square = 1.690). It means that the difference in the behavioral engagement of the three streams is statistically significant. Within-groups variance (Mean Square = 0.263) indicates the individual differences that occurred within the subject groups. The findings cause the null hypothesis (Ho2) to be rejected and it said that TEL does not affect behavioral engagement. Overall, the data indicate that TEL affects the engagement of behavioral streams in different subject streams, and it is highly variable that the students of Arts, Science, and Commerce show differences in the levels of participation, attention, and involvement in the tasks.

Table 4

Impact of Technology-Enhanced Learning on Students' Behavioral Engagement Across Multiple Subjects at the Higher Secondary Level (Post Hoc Analysis)

Comparison	Mean Difference	Std. Error	Sig.	Interpretation
Arts vs Science	−0.310	0.087	.001	Significant
Arts vs Commerce	−0.266	0.094	.014	Significant
Science vs Commerce	0.045	0.060	.734	Not significant

Table 4 shows a post hoc analysis of the behavioral engagement in Arts, Science and Commerce streams after the significant ANOVA. The comparisons reveal that Arts students had large lower behavioral engagement in comparison to both Science (Mean Difference = -0.310, p=.001) and Commerce students (Mean Difference = -0.266, p=.014) and this validates the existence of meaningful differences in the comparisons. Nevertheless, the difference between the Science and Commerce students (Mean Difference = 0.045, p = .734) was not statistically significant and this indicated that both the streams have the same level of behavioral engagement. These results provide the conclusion that there is no constant effect of technology-enhanced learning on behavioral engagement across all streams subject to study, which in turn rejects the null hypothesis, between Arts and Science and Arts and Commerce, but does not reach the null hypothesis between Science and the Commerce students.

Table 5

Impact of Technology-Enhanced Learning on Students' Emotional Engagement Across Multiple Subjects at the Higher Secondary Level (One Way ANOVA)

Source of Variance	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4.038	2	2.019	9.224	.000***
Within Groups	84.485	386	.219		
Total	88.523	388			

Note: ***p < .001

Table 5 shows the results of One-Way ANOVA, which is used to investigate the differences among the students of Arts, Science and Commerce streams regarding emotional engagement following technology-enhanced learning (TEL). The analysis indicates that there is a great influence of TEL in emotional engagement among the subjects (F = 9.224, p <.001) meaning that the mean of emotional engagement is different among at least two groups. The difference between groups variance (2.019) is significantly higher than within-groups variance (0.219), which means that the differences in emotional engagement are related to subject streams and not to randomness. These findings contribute to the null hypothesis (Ho3) being rejected, to ensure that technology-enhanced education does play an important role in the emotional participation of students in the higher secondary level, and to provide the post hoc analysis in order to determine which subject comparisons generate these differences.

Table 6

Impact of Technology-Enhanced Learning on Students' Emotional Engagement Across Multiple Subjects at the Higher Secondary Level (Post Hoc Analysis)

Comparison	Mean Difference	Std. Error	Sig.	Interpretation
Arts vs Science	−0.122	0.079	.273	Not significant
Arts vs Commerce	−0.318	0.086	.001	Significant
Science vs Commerce	−0.196	0.054	.001	Significant

Table 6 displays the post hoc analysis of pairwise differences in emotional engagement among students under Arts stream, Science stream and Commerce stream as a consequence of technology-enhanced learning (TEL). The findings reveal that the Arts vs Science comparison demonstrates a mean difference of -0.122 (p =.273), this is not statistically significant, which means that there is no appreciable difference in emotional involvement in the two streams. However, compared to Arts vs Commerce, the significant mean difference of -0.318 (p =.001) and Science vs Commerce students has a significant mean difference of -0.196 (p =.001) to show that more Commanders are more emotionally engaged than both Arts and Science students. These results explain how the difference between groups is related to the significance of the ANOVA in general, and justify the null hypothesis (Ho3) being rejected in particular comparisons of subjects.

Discussion

The current research was focused on how technology-based learning (TEL) affected the cognitive, behavioral, and emotional involvement of students in Arts, Science, and Commerce streams in higher secondary levels. The results show that there are high variations in the level of engagement among subject streams, which proves that TEL does not impact all students alike.

Cognitive Engagement: The One way ANOVA and post hoc test indicated a significant lower cognitive engagement among Arts students as compared to the science and Commerce students and no significant difference in cognitive engagement between science and commerce students. This is in line with the past researches that indicated that the cognitive benefits of TEL are relatively stronger in those subjects which have organized problem-solving oriented content, e.g. Science and Commerce (Rotar, 2025; Diwan, 2025; Ibrahim et al., 2025). Interactive simulating, adaptive quiz, and concept visualization tools, which are popular in Science and Commerce, can help facilitate more cognitive processing, but Arts subjects might not necessarily take advantage of the TEL analytical and strategic learning capabilities.

Behavioral Engagement: The same trends were observed on behavioral engagement. Arts students were less participatory, less attentive and less involved with tasks that the Science

and Commerce students were. Post hoc test resulted in finding that there was a significant difference between Arts vs Science and Arts vs Commerce but not between Science and Commerce. These findings support the findings of preceding studies that show that TEL enhances active engagement and collaboration in content topics with measurable assignments and interactive digital technologies better (Diwan, 2025; Kearney, 2020). Subjects in arts can involve more reflective and discussion-based activities, and this kind of task will need varying TEL strategies in order to reach similar behavioral engagements.

Emotional Engagement: The analysis of emotive engagement showed that the Commerce students had the greatest rates of emotive involvement, which was far higher than with Arts and Science students. There was no significant difference between Arts and Science, so it could be inferred that the emotional reactions to TEL interventions were similar in both streams. These findings are in line with the previous studies that indicate that individualized feedback, gamification, and interactive online tools contribute to students being more interested, motivated, and entertained (Surlitasari et al., 2023; Shao et al., 2025). TEL tools allowing students to perceive the context of problems in the real world, instant feedback, and monitoring of their performance could be especially useful to Commerce students, which leads to positive learning emotions.

Subject-Specific Implications: In every dimension of engagement, Science and Commerce students were significantly higher performers in comparison to the Arts students, and subject-specific learning outcomes should be evaluated when using TEL tools. According to the previous studies, the efficacy of TEL is meditated by the type of content, teacher facilitation, and student pre-existing levels of digital literacy (Kuznetsov, 2025; Passyn, 2023). The noted discrepancies can be attributed to the fact that the curricula of Science and Commerce are already ready to include digital tools to improve interaction, whereas Arts classes might require more specific TEL plans with a focus on creativity, reflection, and discussion as a way to foster interaction.

Conclusions

1. *Cognitive Engagement:* Technology-enhanced learning has a significantly higher cognitive engagement in Science and Commerce streams than entertainment in Arts, which validates the fact that the effectiveness of TEL relies on the content characteristics of the subject.
2. *Behavioral Engagement:* TEL has a positive effect on behavioral engagement, although Arts students are less likely to engage and less likely to participate in the tasks than Science and Commerce students, which suggests that TEL should be adapted to Arts curricula.
3. *Emotional Engagement:* There is a difference in the level of emotional engagement depending on the subject matter with the highest level of affective involvement being among the Commerce students, as interactions and feedback 9-driven TEL tools induce interest and motivation.

Recommendations

1. The schools are supposed to formulate technology-based learning interventions that match the cognitive requirements and goals of every subject stream. In the case of the Arts students, TEL tools that focus on creativity, critical reflection, and discussion-based activities (e.g. interactive story-telling platforms, digital debates, or multimedia projects) should be introduced to compensate the lack of cognitive interaction witnessed with the students of the Science and Commerce groups.

2. TEL strategies used by teachers should be those that encourage participation, perseverance, and task accomplishment especially in Arts classes. Online projects and some type of real time participation (e.g. polls, quizzes, or virtual group work) can enhance behavioral engagement by offering structured and interactive experiences that encourage students to remain engaged and active.
3. The idea of emotional engagement can be enhanced by including TEL tools that give instant feedback, challenges, and real-life uses of content. Indicatively, students courses in Commerce enjoyed the advantages of contextual simulations and feedback-targeted platforms; the same must be replicated in Arts and Science streams to through the roof in interest, motivation and enjoyment.

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