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Impact of Use of FETL Model in Mathematics Lessons on Student Achievement and Attitudes in Secondary Schools and Postsecondary Institutions in Guyana

Colin Ferreira

Lecturer, Department of Foundation and Education Management, Faculty of Education and Humanities, University of Guyana, Guyana

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ABSTRACT

The purpose of this quasi-experiment research design was to determine the effect of the FETL Model on student achievement and attitudes. Two Guyanese postsecondary institutions (n = 28 and n = 31) and one secondary school with two experimental groups (n = 21 and n = 26) and two control groups (n = 28 and n = 20) participated. Postsecondary students only completed the survey. For the experimental groups, lessons were designed using the FETL Model which included simulation and gamification applications including Khahoot! and PhET Simulation, whereas lessons for the control groups were taught using traditional teaching methods. One-way ANCOVA revealed that the mathematics progress scores of the students who were instructed using the FETL Model were significantly higher than the test results of the control groups. Survey results indicated that students in secondary and postsecondary institutions had positive attitudes towards the FETL Model use. Implications for policymakers, administrators, teachers, and curriculum designers are discussed.

1. Background of the Study

The researcher conducted the study in the Co-operative Republic of Guyana. Guyana is located on the northern coast of South America and shares borders with Venezuela, Suriname, and Brazil. Guyana, an English-speaking, multiethnic, and developing country with a population less than one million, is experiencing rapid growth (Gross domestic product and infrastructural developments) since the country discovered oil in 2015. On a global scale, many countries are experiencing underachievement in mathematics (Chand et al., 2021; Mabena, 2021; Oa Adeneye Awofala, 2023). Guyana, like many countries around the world, is experiencing challenges emerging from global migration, emergence of artificial intelligence in education, and employers' changing skills and knowledge requirements for new employees.

The Government of Guyana through the Ministry of Education developed an education sector plan (2021-2025) aimed at eradicating illiteracy, improving tolerance, modernizing education, and improving performance at all levels (Ministry of Education [MOE], 2021). Guyana has experienced low performance in mathematics at all levels of schooling and in both national and

* Corresponding author's E-mail address: colinferreira01@gmail.com

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regional examinations. The national assessment indicated that less than 50% of students passed mathematics (MOE, 2021). Despite small gains in the pass rates at the National Grade Six Assessment (NGSA), the pass rate remained below 50% (36.5%) in 2021 and rose to 55.51% in 2025 (MOE, 2021; MOE, 2025). At the secondary level, the mathematics performance is more dismal with 36% pass rate at the Caribbean Examinations Council (CXC) mathematics examination (MOE, 2021).

Another issue facing the K-12 education system (nursery, primary, and secondary levels) in Guyana is the influx of refugee children (Spanish speaking) from Venezuela with a total of 740 migrants from April to May 2019 (MOE, 2021). To reduce the inequities in education for the emergent bilingual and native student populations in the ten regions of Guyana, the Ministry of Education piloted and instituted a policy that supported the use of first languages for lesson delivery in classrooms where English was not the native language of students. It is important to note that the Indigenous students or Amerindian students of Guyana were also given the option to be taught in their tribal languages (MOE, 2021). Similar efforts have been made to address special education students in terms of building more special needs schools and training teachers. As it relates to technology in education, MOE has been working to address this problem. For the 453 primary schools, 31% were equipped with information and communications technology (ICT) while at the secondary level (94% of the 116 schools had ICT (MOE, 2022).

However, new and innovative teaching and learning frameworks are urgently needed to effectively cater to all students regardless of their cultural backgrounds, native languages, academic abilities, and socioeconomic status. To promote equity in classrooms for emergent bilingual students, future and currently employed teachers must be certified and possess the knowledge, skills, abilities, and dispositions to teach students whose cultural backgrounds are different from their backgrounds (Ortiz et al., 2022). In addition, both hard skills (technical skills such as information literacy) and soft skills (such as communication, interpersonal, emotional intelligence, negation, business etiquette, and team skills) are needed for graduates to be successful in the workforce but employers are complaining that graduates lack these skills (Hahn & Pedersen, 2020).

2. Literature Review

2.1. Challenges and Innovative Pedagogical Best Practices for K-12 Mathematics Instruction

Mathematics is one of the most challenging academic subjects to teach in K-12 educational institutions (nursery, primary and secondary levels). Mathematics is also one of the subject areas with the lowest academic achievements at all levels of schooling in national and international Mathematics examinations (Tanujaya et al., 2017; Tarteer & Ismail, 2020). Challenges regarding pedagogy are crucial in all aspects of early childhood education including early childhood Mathematics (Dunphy, 2009). Teachers are of the belief that they are confronted with a range of challenges in the teaching of Mathematics in early childhood including:

(1) engaging students in problem-solving and in general processes of Mathematics; (2) building the Mathematical understanding of students from diverse language backgrounds; (3) providing support for students experiencing difficulty with Mathematics; (4) recording students' Mathematical learning (Dunphy, 2009). Dunphy (2009) outlined several recommendations based on early childhood Mathematics research findings that included developing a high-quality early childhood Mathematics program that consists of general and specific

Mathematical processes (problem-solving, reasoning, proof, communication) and dispositions (persistence, curiosity, willingness to experiment) coupled with Mathematical content. There is a plethora of research findings that support the efficacy of a reform-oriented framework to teaching and learning Mathematics (Russo & Hopkins, 2019). In a study with first and second grade students, the results indicate considerable learning gains can be obtained by engaging students with a difficult (cognitively demanding) task and introducing a Mathematics lesson with a task prior to instruction are two traits of a reform-oriented approach to Mathematics instruction (Russo & Hopkins, 2019).

Entrepreneurial elements (such as savings and investment problems) should be included in the curriculum and instruction for students who are both learning and teaching Mathematics, but the challenge is that teachers do not possess knowledge about the entrepreneurial elements (Mahmud et al., 2022). In addition, sentence-based Mathematics problem-solving skills are vital because they can enhance the students' ability to confront different Mathematical problems in their daily lives, foster imagination, build creativity, and improve their comprehension skills (Ling & Mahmud, 2023). However, mastery of these skills remains unsatisfactory for reasons including: (1) difficulty in understanding the Mathematical problems; (2) unable to develop the correct strategy; (3) errors in calculations (Ling & Mahmud, 2023).

There is a plethora of research in Mathematics education highlighting innovative instructional frameworks and teaching and learning resources. A review of literature in Mathematics education revealed a gamut of innovative pedagogies for pre-k to secondary school grade levels Mathematics (Helenius, 2018; Koljonen et al., 2018; Svinvik et al., 2025; Turgut et al., 2024; Weingarden, 2024). Simulation applications are effective in fostering conceptual understanding not only for in-service teachers but for pre-service teachers. For example, simulated environments such as WeBabble, allow teachers to target specific skills premised on how teacher educators have developed the talk graph to be simulated (Svinvik et al., 2025). Turgut et al. (2024) research grounded in the pedagogical technology knowledge (PTK) framework, Mathematical knowledge for teaching (MKT), and computational tools (CT) revealed some interesting findings. The PTK framework consists of three interrelated components:

(1) teachers' mathematical knowledge for teaching; (2) tools use and instrumental genesis (IG); (3) personal orientation (PO). It is important to note that the teacher's mathematical knowledge is not the primary factor that fosters teaching but rather the teacher's subject matter knowledge and pedagogical content knowledge are heavily linked to effective teaching (Turgut et al., 2024). Teachers do believe that employing computational tools in the teaching of Mathematics promotes student engagement, problem-solving skills, and abstraction in the classroom (Sands et al., 2018, as cited in Turgut et al., 2024). Helenius (2018) proposed a conceptual framework that postulates a structured way of looking at the complexity of Mathematics pre-school pedagogy by recommending three dimensions of teacher action relative to Mathematical pedagogy:

(1) pedagogical explication; (2) teacher participation; (3) situational planning. Practice rooted in these principles can lead to thoughtful play-based pre-school practices and create an environment for teaching pre-school Mathematics that not only employs student-teacher interaction but other options as well (Helenius, 2018). As it relates to learning resources, curriculum materials (CMs) including textbooks and teacher guides (TGs) are widely used tools in Mathematics education and TGs have embedded in their text, cultural educational values, and norms (Koljonen et al., 2018). The Realization Tree Method (RTM) is both a research tool for determining Mathematical learning opportunities in classroom discussions

and a learning tool for teachers (Weingarden, 2024). The RTM fosters clarity, availability, and communication of Mathematical ideas and meanings in a lesson or task (Weingarden, 2024). Furthermore, teachers' formative feedback plays a critical role in instructional conversations on such topics as Mathematical patterns or claims in class, and between teachers and students on any unforeseen situation that emerges during instruction (Smit et al., 2022).

Technology plays an integral role in fostering active engagement in classrooms. Employing gamification elements indirectly influenced academic achievement because of their positive impact on engagement in the classroom (Çakıroğlu et al., 2017). Gamification emerged from the boredom traditional activities created since they are naturally uninteresting and fail to stimulate students' attention (Çakıroğlu et al., 2017). Rashid and Asghar (2016) found using path analysis that technology use is a robust predictor of self-directed learning (SDL) and student engagement. Gamification has recently emerged as a medium to enhance engagement using the inclusion of game-like features such as points and badges, in non-game contexts (Looyestyn et al., 2017). Furthermore, research has shown that students have a greater likelihood of remaining engaged in an activity they consider enjoyable and valuable (Looyestyn et al., 2017).

A considerable number of research findings indicate that gamification can increase students' levels of engagement (Alsawaier, 2018). It is important that educators should align educational goals in the process of creating gamification strategies (da Rocha Seixas et al., 2016). In addition, gamification is different from game-based learning and games because it uses elements of games without making the learning process a fully-fledged game (Rivera & Garden, 2021). Gamification as stated before, is using game design elements, game mechanics, and game thinking in non-game activities to motivate students whereas, game-based learning (GBL) is employed to stimulate participation in learning during play to make the learning process more interesting (Al-Azawi et al., 2016).

2.2. Academic Engagement: Culturally and Linguistically Responsive Curriculum and Instruction

The United States and several countries around the world have been challenged with a recurring and expanding underachievement of students from impoverished, urban, rural, and non-mainstream ethnic, racial, and linguistic populations (Gay, 2015). The rapid growth of immigration has created an increased number of culturally and linguistically diverse (CDL) students in K-12 mainstream classrooms in the United States (Zhang-Wu, 2017). To address the challenges posed by the growing CDL student populations, culturally and linguistically responsive (CLR) pedagogy has been developed, and teachers can promote CLR instructional practices by designing teaching and learning activities and instruction that cater to students' culture and language backgrounds (Zhang-Wu, 2017). Culturally relevant or culturally congruent teaching (CRT) emerged as a solution to the traditional curricular and instructional methods that failed to meet the needs of student of color, immigrant students, and students from lower socioeconomic families (Vavrus, 2008). Teachers can develop culturally responsive practices by constructing a dynamic knowledge base that changes to reflect shifts in students, contexts, and subject matter developments (Ebersole et al., 2016).

2.3. Impact of Artificial Intelligence in Education

The researcher presented a brief discussion on the benefits of technology in education rather broadly. In this section, the impact of artificial intelligence (AI) is outlined. The field of Artificial Intelligence in Education (AIED) has experienced radical changes over the past 25 years (Roll & Wylie, 2016). AI is used in several ways in education including administration, instruction, and learning. In administration, AI can perform tasks faster, identify learning styles and preferences of each student, provide feedback and graded work in a timely manner, and help them create personalized learning plan (Chen et al., 2020). For instruction, AI can customize teaching methods for each student based on personal data, create personalized learning plans for each student, and permit instruction to occur outside of the classroom (Chen et al., 2020). As it relates to learning, AI can discover learning gaps and deficiencies and cater to them early in education, predict career pathways for students using studying data, and determine learning state and apply intelligent adaptive interventions to students (Chen et al., 2020). Furthermore, AI plays a pivotal role in promoting the United Nation's Sustainable Development Goal 4 which seeks to remove barriers to equitable and inclusive access to quality education. AI technologies are employed to provide equitable and inclusive access to education for marginalized people (including disabled people) and communities, refugees, school dropouts, and those living in remote regions (Pedro et al., 2019). Chen et al. (2022) have outlined a range of ways that AI has been used in Education:

(1) intelligent tutoring systems (ITSs) for special education; (2) natural language processing (NPL) for language education; (3) educational robots for AI education; (4) educational data mining (EDM) for performance predictions; (5) neural networks for teaching evaluation; (6) affective computing for learner emotion detection; (7) discourse analysis in computer supported collaborative learning (CSCL); (8) recommender systems for personalized learning.

2.4. Theoretical Frameworks

This research study is grounded in three theoretical frameworks: constructivism learning theory, technology acceptance model (TAM), and expectancy-value theory. Hein (1991) outlined several principles of learning including: (1) students through an active process, learn by using sensory input and construct meaning out of it; (2) students learn to learn and they are learning which involves constructing meaning and systems of meaning; (3) learning through physical actions and practical activities are not adequate and so learners must construct meaning through a mental process called reflective activity; (4) language plays a pivotal role in learning as students talk to themselves about what they are learning; (5) learning is a social activity in which students intimately link what is taught to other individuals, their teachers, fellow students, family members, and acquaintances; (6) learning is contextual; (7) learning requires prior knowledge; (8) learning occurs over time; (9) learners need to be motivated to learn.

Constructivism learning theory postulates that learners construct knowledge for themselves both individually and socially as they learn (Hein, 1991). Constructivism is a framework that argues that teaching and learning are rooted in cognition (learning) engendered by thoughts (Bada & Olusegun, 2015). Constructivists are of the view that students learn by connecting new knowledge to their prior knowledge and this learning process is influenced by the context in which lessons are taught as well as students' attitudes and convictions (Bada & Olusegun, 2015). It is crucial that educators should not only impart knowledge to students but provide opportunities for students to construct knowledge in their own minds (Efgivia et al., 2021). Essentially, students learn after they have gained experience from what they have learned by creating knowledge from these experiences (Suhendi, 2018).

Researchers have used the technology acceptance model (TAM) in a considerable number of studies on information and communications technology to gain an understanding and explanation of user behaviors (Alomary & Woollard, 2015). The TAM is based on six determinants on the perceived ease of use: (1) computer self-efficacy; (2) computer playfulness; (3) computer anxiety; (4) perception of external control; (5) perceived enjoyment;

(6) objective usability behaviors (Alomary & Woollard, 2015). According to the TAM, individuals' attitudes about the use of an application can be predicted by both perceived usefulness and perceived ease of use (Chen et al., 2011). TAM has been proven to be an effective theoretical framework in understanding and explaining user behavior in the information system implementation (Chen et al., 2011).

A connection to Bandura (1982) findings was made by Chuttur (2009) when he expounded that self-efficacy is congruent to perceived ease of use. Despite the TAM was developed for information systems in the information technology and business industries, its applications can be used in education. The rapid development of information technologies has revolutionized educational institutions including web-based e-learning (electronic learning) as a substitute education modality (Zaineldeen et al., 2020). This new learning platform has created advanced learning context and provided students with an effective tool for collaborative learning (Zaineldeen et al., 2020). A plethora of studies have investigated the application of TAM in education in a range of learning technologies including personal learning environments (PLEs), learning management systems (LMS), open-source LMS Moodle, and commercial LMS Blackboard (Zaineldeen et al., 2020).

The three primary predictors of academic achievement are student self-efficacy, behavioral management, and emotional engagement (Olivier et al., 2019). The expectancy-value theory suggests that prior self-efficacy engenders emotional engagement, behavioral engagement, and achievement (Olivier et al., 2019). Furthermore, self-efficacy and emotional engagement stimulate behavioral engagement such as effort, attention, and compliance (Olivier et al., 2019). Individuals' expectations for success and the value they place in succeeding are key determinants of their motivation to perform different achievement tasks (Wigfield, 1994). An individual's belief in his or her abilities plays a vital role in different motivation theories (Wigfield & Eccles, 2000).

The expectancy-value theory can be applied to examine student motivation in different academic subjects and grade levels. In mathematics education, researchers have inferred that if students can use empirical reasoning to justify a mathematical statement, then an example-based justification provides students with certainty that the general mathematical statement is true (Weber et al., 2020). Essentially, the expectancy-value theory is a popular theory used to predict students' learning performance, persistence, and aspirations (Loh, 2019). Fielding-Wells et al. (2017) indicated that the expectancy-value motivation theory (EVT) provides three general motivation-related questions that describe aspects of motivation related to expectancy, values, and goals:

1. Can I do the task?
2. Do I want to do this task and why?
3. What do I have to do to succeed in this task?

2.5. The Ferreira's Ecosystem for Teaching and Learning (FETL) Model

The literature review reveals that traditional methods of teaching and learning are no longer effective in meeting the needs of 21st-century students. The Ferreira's Ecosystem for Teaching and Learning (FETL) Model is an innovative framework that has reimagined and redesigned lesson planning and lesion delivery. See Ferreira (2022) for a detailed explanation of each stage and how the FETL Model can be implemented in lesson planning and lesson delivery. The FETL Model consists of five drivers that inform the lesson planning process, learning activities, and assessments including External Environments, Student Profiles, Assessment Data, Curricula and Standards, and Internal Environments. It promotes stimulating introductions to activate prior knowledge and experiences and uses a gamut of instructional and assessments best practices. The teacher serves as a facilitator to the learning process in the Developmental and Execution Stage providing instruction to whole class, small groups, one-on-one, and using artificial intelligence (AI) stations for personalized learning and assessments. All lessons end with demonstrating of learning (DOL) activities and reflections for both teachers and students. It is important to mention that the items in each component (For example, External Environments) of FETL Model are not exhaustive which means more items can be added to each component to reflect new developments and advancements in the different industries.

3. The Purpose of the Study

The purpose of this quasi-experiment research was two-fold: (a) to obtain empirical evidence on the influence of Ferreira's Ecosystem for Teaching and Learning (FETL) Model on students' academic performance in Mathematics in secondary schools in Guyana; (2) to determine the influence of the use of the FETL Model on students' attitudes in secondary and postsecondary institutions.

3.1. Research Questions

1. RQ1. What is the effect of using the FETL Model in Mathematics lessons on student achievement?
2. RQ2. What are the attitudes of students towards instruction in which the FETL Model is used?

4. Methodology

4.1. Design

A quantitative research method with a quasi-experimental design and surveys were used in this research in the secondary school and postsecondary institutions. The decision to use a quantitative method and quasi-experimental design was based on the fact the classes in schools were fixed which did not allow for random assignments of students to the control groups and experimental groups.

The researcher selected Mathematics as the content area to be investigated. Students in the experimental groups and control groups completed a pretest at the beginning of the first lesson and a post-test at the end of the study. The study ran for three weeks in accordance with the school's timetable for Mathematics. In the experimental groups, teachers who regularly teach these students were provided guidance in preparing their lesson plans according to the FETL Model which included the use instructional technology (Desmos, Quizizz, Kahoot!, PhET Simulation, Padlet, and GeoGebra) and delivered their lessons using the school's smartboard, whereas teachers who regularly teach students in the control groups taught using their traditional methods (district's lesson plan format and teachers' non-technology delivery methods). The only difference between the designs of the lessons for the experimental groups and control groups was that the FETL Model was used with the experimental groups which employed technology integration for simulations, gamifications, and assessments, and the control groups used traditional lesson plans and delivery methods which did not use technology.

The FETL Model's lesson plan and lesson delivery aimed to increase academic engagement time, student motivation, culturally and linguistically responsive pedagogy, meaningful and relevant learning experiences, interactive teaching, visualization of abstract concepts using simulation software and websites, gamification, personalized learning, and content immersion.

As a result, notebooks and other learning and instructional materials prepared by the teachers of the experimental groups were not used during the study. The teachers who taught the experimental groups underwent three hours of professional development that included: (1) the implementation of the FETL Model (planning and delivery of the lessons); (2) recording the anonymous pretest, post-test, and previous term scores on the data forms; (3) administering the anonymous Student Experience and Academic Engagement (SEAE) questionnaires; (4) distributing and collecting parental consent forms. Throughout the research process, teachers and lecturers were provided with continued support. At the postsecondary level, lecturers only administered the questionnaires to obtain data on students' attitudes about being taught using the FETL Model. Lecturers also underwent three hours of training in the aforementioned areas for the secondary school teachers.

4.2. Samples and Procedures

The researcher assigned each of the ten regions to a number corresponding to their official names (1 for Region One, 2 for Region Two and so on) and then used technology (TI-nspire CX II calculator, randInt (1, 10, 2)) to randomly select two regions from the ten regions of Guyana. The secondary schools in the two selected regions were assigned numbers and those numbers were used in the random selection process to select two schools. However, only one secondary school completed the research. Similarly, the postsecondary institutions were assigned numbers and the researcher used technology to randomly select the two postsecondary institutions from the population of postsecondary institutions in Guyana.

The samples of the study consisted of 95 students from one secondary school and 59 students from two postsecondary institutions. A letter outlining the rationale for the research and consent forms for parents and teachers were sent to the school district leadership, academic director, and department chair of the two postsecondary institutions to obtain approval to conduct the research. Approvals were granted for the three institutions. The lecturers and teachers completed their consent forms. In addition, the parents completed their consent forms. PDF copies of all completed consent forms were emailed to the researcher prior to the commencement of the study. The consent forms for parents, secondary school teachers, postsecondary students, and postsecondary lecturers clearly described the research including a description of the study, confidentiality, risks and benefits, freedom to withdraw or refuse participation, and questions (contact information for researcher).

The secondary school teachers and postsecondary lecturers conducted the study and provided the anonymized data to the researcher including the previous term scores (covariant), pretest and post-test scores, and the survey (SEAE) results. Postsecondary students completed the Student Experience and Academic Engagement (SEAE) survey only. Secondary school students completed a pretest and a post-test. The experimental groups completed the SEAE at the end of the study. The researcher reviewed all lesson plans to ensure that all components of the FETL Model were included. Teachers and lecturers refined their lesson plans taking into account the researcher's feedback. Confidentiality procedures were strictly followed. At the end of the study, only anonymized data were emailed to the researcher including pretest, post-test, and previous term Mathematics scores and SEAE results.

4.3. Measurement: Normality, Validity and Reliability Measures

All SPSS normality, validity, and reliability test results are reported in the results section. In addition to Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) tests, other tests for normality include using a histogram (Hatem et al., 2022). The researcher followed the steps by Radhakrishna (2007) to develop a valid and reliable questionnaire which involved: (1) background (determining the participants and their background for the study); (2) questionnaire conceptualization (creating questions, content from literature or theoretical framework, and translating objectives into content); (3) format and data analysis (choosing suitable scales of measurement, questionnaire layout, format, ordering questions, and deciding on levels of data for analysis such as ANOVA); (4) establishing validity (using a panel of experts and a field test and considering the different types of validity including content, construct, criterion, and face); (5) establishing reliability (using a pilot test and reliability tests such as Cronbach's alpha to improve the reliability score to 0.70 or greater). Content validity refers to the degree to which the instrument includes all items that are required to adequately measure the construct of interests (Roy et al., 2023). Content validity is highly recommended when creating a new instrument (Taherdoost, 2016). Consequently, experienced, and certified teachers developed the pretest and post-test in alignment with the Caribbean Secondary Education Certificate (CSEC) test guidelines and syllabus. The post-test included the same format and topics as the pretest.

The researcher employed a three-factor Student Experience and Academic Engagement (SEAE) scale, and the experimental groups completed this to investigate the students' attitudes towards the use of the FETL Model which included incorporating technology in instruction and learning activities, meaningful and relevant learning (including culturally and linguistically responsive instruction and real-world applications), and 4C's (Collaboration, Communication, Creativity, and Critical Thinking). The scale consisted of 17 items, and the students were asked to state their opinions on a 5-point Likert scale with *Strongly Disagree* = 1, *Disagree* = 2, *Neither Agree nor Disagree* = 3, *Agree* = 4, and *Strongly Agree* = 5 (See Appendix A for the SEAE scale). The SEAE consisted of three subconstructs (Technology, Meaningful and Relevant Learning, and 4C's). Items 1, 2, 3, 4, 5, 14, and 15 targeted students' attitudes towards the use of technology in instruction and learning activities. Items 6, 7, 8, and 9 targeted meaningful and relevant learning (including culturally and linguistically responsive instruction and real-world applications). Items 10, 11, 12, 13, 16, and 17 targeted the 4C's.

Face validity assesses the questionnaire in terms of feasibility, readability, consistency of style and formatting, and clarity of the language employed (Taherdoost, 2016). Face validity was assessed using certified and experienced secondary school teachers and postsecondary lecturers to rate each of the 17 items on a scale of 5 in four categories: (a) clarity and simplicity; (b) relevance and purpose; (c) specificity; (d) balanced and unbiased. Some questions were refined for scores below four to ensure that each item met the four categories which enhanced face validity. Construct validity refers to the extent to which an instrument measures the theoretical construct that it is designed to measure (Roy et al., 2023). Construct validity was assessed by Exploratory Factor Analysis (EFA) with Principal Axis Factoring. Criterion validity measures the degree to which the instrument is related to an outcome (Taherdoost, 2016). Principal component analysis (PCA) is a multivariate statistical method that is employed to combine the information from several variables observed on the same subjects into fewer variables called principal components (Greenacre et al., 2022). Criterion validity of the SEAE was evaluated using Pearson's Correlation. In social and organizational sciences, Cronbach's alpha reliability is one of the most widely used measures of reliability (Bonett & Wright, 2015). Cronbach's alpha provides a measure of internal consistency of a test or scale which is expressed between 0 and 1 (Tavakol & Dennick, 2011). Cronbach's alpha was computed to determine if the multiple question Likert scale questionnaire was reliable, and it determined that the SEAE was accurately measuring the variable of interest.

5. Results

5.1. SEAE Analysis

In this section, the researcher presents the results from the Student Experience and Academic Engagement (SEAE) survey with the FETL Model (RQ2) and the influence of the FETL Model on student achievement in Mathematics (RQ1). The researcher used IBM SPSS Version 29 to conduct all statistical analyses and an alpha level of .05 was used in all statistical tests. The researcher conducted validity tests on the two raters' scores for the SEAE. The inter-rater reliability was validated using Cohen's kappa, Krippendorff's alpha, and Intraclass Correlation Coefficient (ICC). All validity scores were considered relatively high (see Table 1) including Cohen's kappa of $\alpha = 0.89$ (McHugh, 2012), Krippendorff's alpha of $\alpha = 0.93$ (Krippendorff, 2011), and ICC score of $\alpha = 0.96$, (Bockhorn et al., 2021) which indicated that the two raters did agree. As it relates to the ICC, the confidence interval for the average measures was 95% CI [0.89, 0.99]. The ratings for Rater 1 ($M = 4.5, SD = 0.6$) and Rater 2 ($M = 4.6, SD = 0.6$) were relatively close.

Table 1. Interrater Reliability for Cohen's kappa, Krippendorff's Alpha, and ICC

Cohen's kappa	Krippendorff's Alpha	Intra-Class Correlation
0.89	0.93	0.96

Pearson's Correlations was used to assess the criterion validity of the SEAE for the three institutions. Absolute value Peason's Correlation coefficients ranging from .60 to 1.00 are considered moderate to strong (Schober et al., 2018). The criterion validity analysis indicated statistically significant scores ($p < .001$) for all data sets, which meant that the items were valid. The values from the correlations table were crosschecked with the critical value in the table of critical values for Pearson's r and all computed values were greater than the critical value of 0.37 (for one postsecondary institution). As discussed in the measurement section, face validity and content validity were assessed using a panel of experts for the pretest and post-test and SEAE. In addition, Cronbach's alpha (α) was computed to determine if the multiple question Likert scale questionnaire was reliable. A Cronbach's alpha score of 0.86 was computed for the SEAE. Izah et al. (2023) stated that higher levels of Cronbach's alpha, which exceed 0.75, indicate a robust internal consistency (which means that the items within the scale instrument reliably measure the same underlying construct). The SEAE consisted of three subconstructs (Technology, Meaningful and Relevant Learning, and 4C's). The computed Cronbach's alpha value (α) was 0.80 for the Technology items, Meaningful and Relevant learning items received a Cronbach's alpha value (α) of 0.79, and items for the 4C's got a Cronbach's value (α) of 0.90, indicating that the measure had good reliability.

Using the SEAE, the researcher analyzed data collected from the students who had been learning in the FETL Model learning environment to find answers to the second research question, "What are the attitudes of students towards instruction in which the FETL Model is used?" Descriptive statistics were computed to analyze the students' experience with the FETL Model (See Appendices A, B, C, and D for all 17 items). The samples consisted of 9 (32.1%) male and 19 (67.9%) female respondents (n = 28) from an on-campus Science class at one postsecondary institution and 9 (29.0%) male and 22 (71.0%) female respondents (n = 31) from an online Science class from another postsecondary institution. The samples from the secondary school consisted of 21 (44.7%) male and 26 (55.3%) female respondents (n = 47) for the experimental groups and 23 (47.9%) male and 25 (52.1%) female respondents (n = 48) from the control groups. For the first postsecondary institution, as seen in Table 2, for Items 1 and 2 of the Technology construct, Strongly Agree and Agree had 85.8% (See Figure 1) and 75% cumulatively of the students in agreement, respectively. For Items 7 and 9 of the

Meaningful and Relevant Learning, 100% and 96.4% respectively agreed, and for Items 16 and 17 of the 4C's construct, 78.6% and 67.9% respectively agreed. For the second postsecondary institution, Items 1 and 2 received lower percentages (71% and 35.5% respectively) compared to the first postsecondary institution (See Appendices B and C). Items 7 and 9 received lower percentages (90.3% and 71% respectively) and Items 16 received a slightly lower, but Item 17 got a much higher percentages (67.8% and 87.1% respectively) when compared to the first postsecondary institution. For the secondary school (See Appendix D), Items 1, 2, 7, 9, 16, and 17 received combined agreement scores of 89.4%, 57.5%, 83%, 78.7%, 72.4%, and 65.9%, respectively.

Item 4 which was "Simulations and visualization using technologies (like Desmos VR, and PhET Simulations) help students to gain a deeper understanding of the concept," received 91.3%, 92.8%, and 67.8% for combined agreement respectively for the secondary school, postsecondary-1, and postsecondary-2. Item 10 which was "I enjoy working in groups with my classmates" received low percentages for combined agreement for both postsecondary institutions (13% and 35.8%) compared to 66% for the secondary institutions. These high percentages indicated a strong preference and positive experience with the FETL Model which included use of technology, meaningful and relevant learning, and the 4C's (Communication, Collaboration, Critical Thinking, and Creativity) in the teaching and learning process for the students in these secondary and postsecondary institutions in Guyana in both face-to-face and online classrooms.

Table 2. Descriptive Statistics (%) of Data Collected by SEAE Instrument

Variable	StronglyDisagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
Item 1	3.6	0.0	10.7	17.9	67.9
Item 2	7.1	3.6	14.3	46.4	28.6
Item 7	0.0	0.0	0.0	50.0	50.0
Item 9	0.0	0.0	3.6	46.4	50.0
Item 16	7.1	0.0	14.3	28.6	50.0
Item 17	3.6	7.1	21.4	42.9	25.0

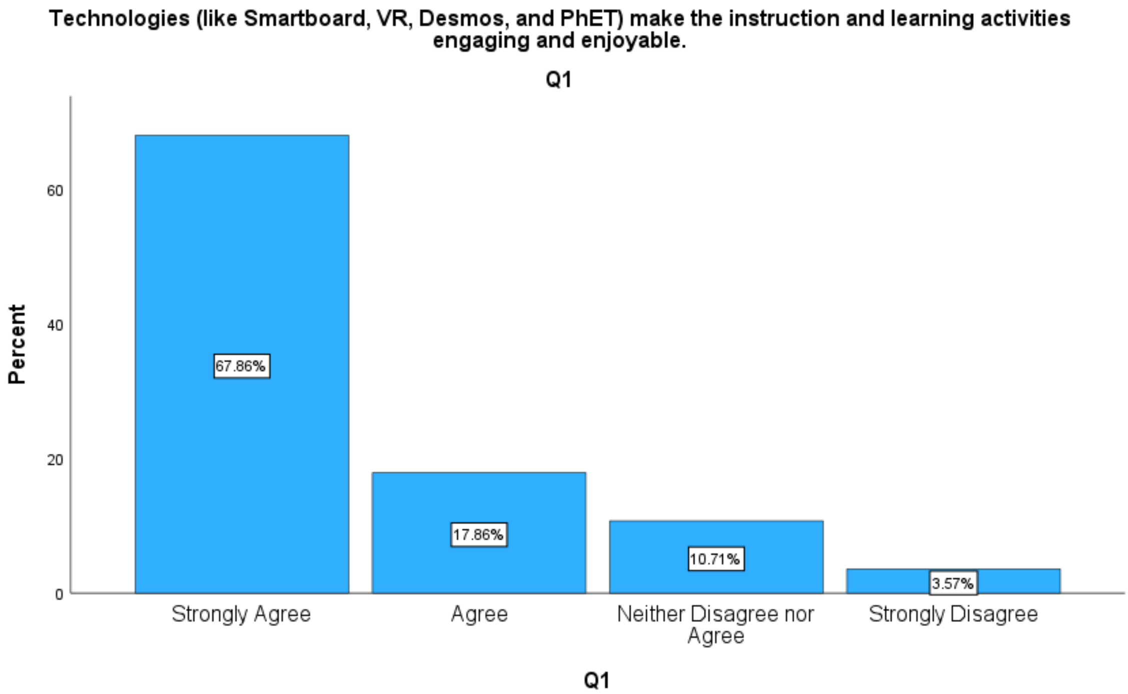

Figure 1. Item 1 Response Percentage Breakdown for Postsecondary-1

The researcher used Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of Sphericity to assess the factorability of the data. Kaiser's Criterion and Scree test were used to determine the fixed number (three factors for the three constructs) of factors to be extracted. Varimax orthogonal factor rotation method was used to minimize the number of variables that had high loadings on each factor. The data collected were analyzed using principal component analysis (PCA). The indicators of factorability were good for all data sets. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was 0.80, which is in the Adequate range of 0.60 to 1.00 (Shrestha, 2021). Furthermore, Bartlett's Test of Sphericity yielded a significant result, $\chi^2(136) = 251.95, p < .001$, which showed that the correlation matrix of measured variables was significantly different from an identity matrix which meant the items were sufficiently correlated to load on the components of the measure. When using the correlation matrix, researchers are advised to only examine the eigenvalues of each component and only interpret components with an eigenvalue greater than 1.00 (Grossman et al., 1991). Six components with an eigenvalue greater than 1.00 were revealed. (See Figure 2).

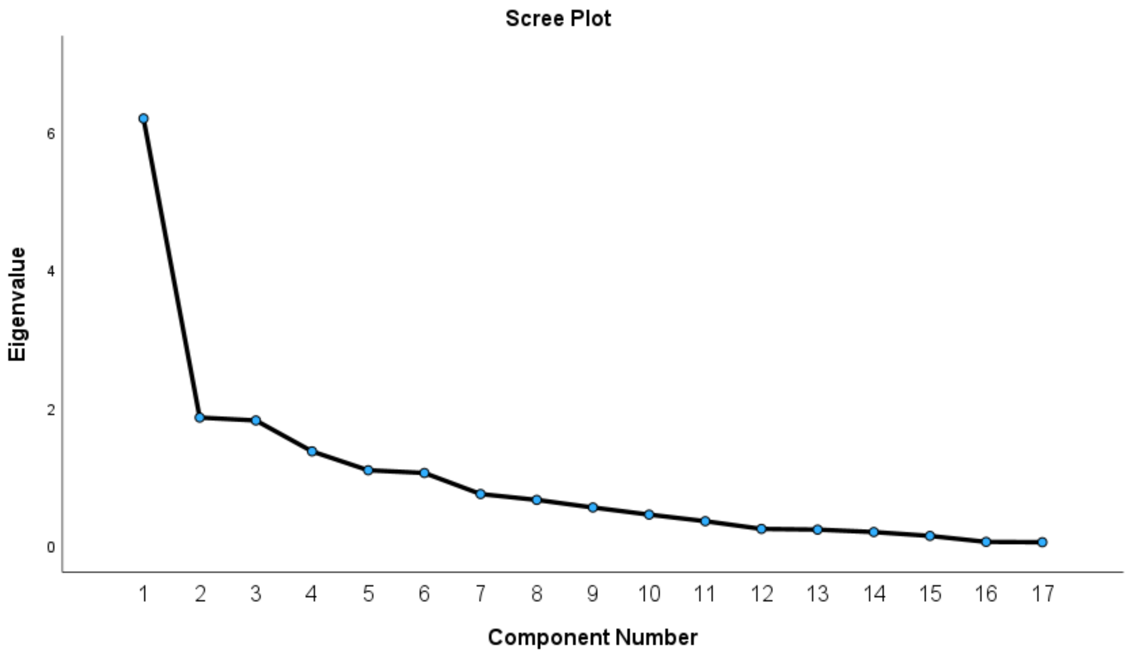

Figure 2. Scree plot for components of the instrument

In the scree plot (Figure 2), there were six components in the sharp descending part of the plot with eigenvalues greater than 1.00. However, only three components were used in the extraction. The total variance explained by the first three components was 58.0% and 79.0% for the first six components. The loadings of the three factors of Technology use in instruction, Meaningful and Relevant learning, and 4C's (Communication, collaboration, critical thinking, and creativity) are shown in Table 3. Items 1, 2, 3, 4, 5, 6, 8, 10, 14, 16, and 17 were loaded on the Technology use factor, items 11, 12, 13, 16, and 17 were loaded on the 4C's, and items 7, 10, 15, and 16 were loaded on the Meaningful and relevant learning factor (see Table 3). Interestingly, Item 9 was not loaded on the first three components despite 96.4% accumulatively in agreement (Agree and Strongly Agree) and the absolute value below was set to 0.40 for factorial analysis. The loadings (ranges from -1 to 1 and 0 means a weak influence) highlight which regions in the data set have the largest effect on each component and loadings close to -1 or 1 mean that the variable strongly impacts the principal component (Cozzolino et al., 2019). Principal components with eigenvalues greater than 1.00 are used and the value of a contribution is between 0 and 1 for a given component (Abdi & Williams, 2010). The larger the value, the more the observation contributes to the component (Abdi & Williams, 2010). Comparable results were obtained for the second postsecondary institution and the secondary school (See Appendices E and F). Similar Scree plots were obtained for the second postsecondary institution and secondary school (See Figure 3 in Appendix E and Figure 4 in Appendix F).

Table 3. Postsecondary-1 Items Representing Technology Use, Meaningful and Relevant Learning, and 4C's

Items	Technology Use	4C's	Meaningful and Relevant Learning
Item 5	.904		
Item 4	.881		
Item 14	.815		
Item 8	.724		
Item 1	.723		
Item 2	.659		
Item 6	.652		
Item 17	.620	.425	
Item 3	.601		
Item 10	.552		-.456
Item 16	.517	.433	.476
Item 12		.879	
Item 13		.803	
Item 11		.540	
Item 9			
Item 15			.692
Item 17			.669

Note. The absolute value below was set to 0.40 for factorial analysis.

5.2. Quasi-Experiment Analysis

The researcher conducted several statistical analyses using IBM SPSS Version 29 to provide answers to the first research question: RQ1. What is the effect of using the FETL Model in Mathematics lessons on student achievement? Pre-post research designs are employed widely in psychological and educational research to either assess changes in outcomes between two time points and/or to compare outcomes in dependent groups (Johnson, 2016). Researchers should check for missing data, outliers, and ensure that the basic assumptions of analysis of covariance (ANCOVA) including normality and homogeneity of variance are met before using the ANCOVA model for analysis (Johnson, 2016). In addition, ANCOVA models have two additional assumptions that must be met including linearity and homogeneity of regression slopes (Johnson, 2016). The assumptions for the analysis of the covariance test were assessed to determine if this test was appropriate for the data analysis.

Firstly, the researcher conducted normality checks to ensure that the data sets for the control and experimental groups came from Normal distributions. As shown in Table 4, the previous term scores which were used as the covariant in this study, met the normality requirements determined by the Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) tests which revealed non-significant results (p = .195 and p = .471 respectively). In addition, checks for outliers revealed that all absolute standardized values were less than 3.29.

Table 4. Tests of Normality Using Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW)

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Previous Term Scores	.08	95	.195	.99	95	.471

Secondly, Hatem et al. (2022) provided ranges for interpreting skewness including symmetrical (-0.50 and 0.50), moderately skewed (-1.00 and -0.50 or 0.50 and 1.00), highly skewed (-1.00 or greater than 1.00). As it relates to kurtosis, a value close to zero is considered a normal distribution, a value less than 0 is considered light tailed, and a value greater than zero is considered heavy-tailed (Hatem et al., 2022). The researcher subtracted pretest scores from post-test scores to determine the progress scores (covariant). As shown in Table 5 and based on Hatem et al. (2022), both progress scores and previous term scores met normality requirements in terms of skewness and Kurtosis.

Table 5. Students' Previous Term Scores and Progress Scores

	n	**Min.**	**Max.**	***M***	***SD***	**Skewness**	**Kurtosis**
Progress Scores	95	-29.0	58.0	19.3	15.8	-0.26	0.70
Previous Term Scores	95	22.0	96.6	56.7	18.9	0.32	-0.94

Thirdly, as recommended by Johnson (2016), the researcher conducted further statistical tests for basic assumptions of analysis of covariance (ANCOVA) including homogeneity of variance, and linearity and homogeneity of regression slopes (Johnson, 2016). The researcher used the Levene's test for equality of variances to assess the homogeneity of variance assumption and got a non-significant result ($p = .069$) based on mean and the Test of Between-Subjects effects was non-significant ($p = .162$) for groups. A test of homogeneity of slopes to evaluate the assumption about whether the relationship between the previous term scores and the progress differed significantly as a function of the independent variable of the group, $F(1, 91) = .002, p = .962 > .01$. As shown in Table 6, the result of this test was not significant which meant the slopes were homogeneous and a one-way ANCOVA was appropriate for data analysis.

Table 6. Test of Homogeneity of Slopes Results

Source	***SS***	***df***	***MS***	***F***	**Sig.**	**Partial Eta Squared**
Previous Term Scores	280.82	1	280.82	0.80	.373	.009
Group * Previous Term Scores	0.82	1	0.82	.002	.962	.000
Error	31921.47	91	350.79			
Total	339197.72	95				
Note. $R^2 = .048$ (Adjusted $R^2 = .016$).						

Finally, given that the assumptions of the one-way ANCOVA were met in the aforementioned statistical analyses, the researcher conducted the ANCOVA test and got the results shown in Table 7 and Table 8. Based on Table 7, the experimental groups ($M = 60.7$) scored higher than the control groups ($M = 52.8$) after the means were adjusted taking into account the previous term scores.

Table 7. Adjusted Mean of Progress Scores of Student Groups

	n	**Actual *M***	**Adjusted *M***
Experimental Group	47	60.4	60.7
Control Group	48	53.1	52.8

As can be seen in Table 8, an analysis of covariance (ANCOVA) indicated that the effect of the FETL Model on student achievement in Mathematics was significant, $F(1, 92) = 4.14, p = .040 < .05$. In other words, the use of the FETL Model in the lessons with the experimental groups resulted in these students receiving higher scores in their Mathematics tests. The partial eta squared value showed that 4.3% of the variance in post-test scores was explained by using the FETL Model when controlling for the previous term scores.

Table 8. ANCOVA Results for the Difference Between Experimental and Control Groups

Source	*SS*	*df*	*MS*	*F*	Sig.	Partial Eta Squared
Previous Term Scores	327.11	1	327.11	0.94	.334	.010
Group	1437.96	1	1437.96	4.14	.040	.043
Error	31922.28	92	346.98			
Total	339197.72	95				
Note. $R^2 = .048$ (Adjusted $R^2 = .027$).						

6. Discussion

The findings of this research project corroborate the findings revealed in the literature review. The Student Experience and Academic Engagement (SEAE) survey provided answers to the second research question: "What are the attitudes of students towards instruction in which the FETL Model is used?" Firstly, teaching and learning activities must cater to the diverse cultural backgrounds, academic abilities, career interests, and native languages of students to promote meaningful and relevant learning experiences and active engagement. Instruction and learning activities must cater to the culturally and linguistically diverse students (CDL) by employing culturally and linguistically responsive pedagogy (Ebersole et al., 2016; Gay, 2015; Vavrus, 2008; Zhang-Wu, 2017). For the on-campus postsecondary institution, Items 6, 7, 8, and 9 targeted Meaningful and Relevant Learning construct. Item 7 received a combined 100% for Strongly Agree and Agree which was "Topics become meaningful when the teacher uses real-world examples and applications from my town/village, country, and from around the world." Item 9 received a combined 96.4% for Strongly Agree and Agree which was "Topics become relevant and exciting when I can connect them to my career aspirations, current interests, identity, prior knowledge, and experiences." Items 6 and 8 (See Appendices A and B) received a combined 57.1% and 89.3% for Strongly Agree and Agree.

These high percentages underscore the importance of incorporating students' cultural backgrounds, interests, academic abilities, and native languages in curriculum, instruction, and assessment to foster active engagement, and meaningful and relevant learning experiences. In addition, these findings are aligned with the theoretical frameworks that this research project was grounded including constructivism learning theory, technology acceptance model (TAM), and expectancy-value theory. Learning employing practical activities and physical actions are insufficient and thus learners must construct meaning through a mental process called reflective activity (Hein, 1991).

Furthermore, learning is contextual and social, requires prior knowledge, and connections must be made to the students' background (Hein, 1991). Constructivism posits that students learn by connecting new knowledge to their prior knowledge which is influenced by context, students' attitudes, and convictions (Bada & Olusegun, 2015). The technology acceptance model (TAM) consists of six determinants (see Alomary & Woollard, 2015) but the one that needs highlighting based on these findings is perceived enjoyment which speaks to the power of gamification in education. The expectancy-value theory postulates that prior self-efficacy engenders emotional engagement, behavioral engagement, and achievement (Olivier et al., 2019).

Second, the benefits of incorporating artificial intelligence in education (AIED) and other technologies have been widely reported in research findings including: (a) personalized learning (Mustapha & Kashefian-Naeeini, 2017); (b) using gamification to increase students' levels of engagement (Al-Azawi et al., 2016; Alsawaier, 2018; Rivera & Garden, 2021); (c) intelligent tutoring systems for special education students and natural language processing for language education (Chen et al. (2022); (d) catering to Gen-Z (digital natives) and subsequent generations (Mustapha & Kashefian-Naeeini, 2017). Students in the experimental groups at the secondary school and postsecondary institutions were taught and assessed using simulation and gamification software (PhET Simulation, Desmos, GeoGebra, Padlet, Quizizz, and Khahoot!). Items 1, 2, 3, 4, 5, 14, and 15 targeted Technology construct and all items received a minimum of 50% combined Strongly Agree and Agree (See Appendices D and F).

Item 1 received a combined of 85.8%, which was "Technologies (like Smartboard, VR, Desmos, and PhET) make the instruction and learning activities engaging and enjoyable." Item 4 received a combined 92.8% for Strongly Agree and Agree, which was "Simulations and visualization using technologies (like Desmos VR, and PhET Simulations) help students to gain a deeper understanding of the concepts." These findings reinforce the calls for equipping all levels of schooling (nursery, primary/elementary, secondary, and postsecondary) with technologies including artificial intelligence, virtual reality (VR), assistive and adaptive technologies to foster equity and immersive learning experiences in all classrooms.

Finally, an urgent need for new and innovative lesson planning and lesson delivery methods that consist of stimulating lesson introductions, authentic assessments (both quantitative and qualitative assessments), reflective practices, and a comprehensive understanding of students' characteristics, curriculum, cultural and institutional context (Iqbal et al., 2021; Kizi, 2024; Milkova, 2012; Womack et al., 2015). Items 10, 11, 12, 13, 16, and 17 (see Appendices A and F) targeted the 4C's (Communication, Critical Thinking, Creativity, and Collaboration) construct. Item 16 received a combined 78.6% for Strongly Agree and Agree, which was "I can demonstrate my knowledge and understanding of topics in other ways than just written tests."

Item 17 received a combined 67.9% for Strongly Agree and Agree, which was "Students should be given opportunities at the end of the lesson/lecture to reflect anonymously on their learning experiences and state what they understood well or did not understand and what they need further explanations on." Items 10 and 11 received a combined 35.8% and 53.5%, respectively. Item 10 was "I enjoy working in groups with my classmates." Item 13 received a combined 67.9%, which was "I enjoy opportunities where students can provide their own unique solutions to a problem." Analysis of the secondary school SEAE revealed comparable results (See Appendix B).

A quasi-experiment was conducted in a secondary school in Guyana to provide answer the first research questions: What is the effect of using the FETL Model in Mathematics lessons on student achievement? The results of the quasi-experiment were statistically significant which means that the FETL Model was effective in improving students' Mathematics achievement scores when controlling for their previous term Mathematics scores.

These findings are not surprising because all components of the FETL Model are supported by research findings including the five drivers, stimulating introduction strategies, development and execution stage, instructional and assessments toolkits, and conclusion and reflections. The development and execution stage consists of four instructional formats (whole class, small groups, one-to-one, and AI-driven stations) that promotes personalized learning, the 4C's, simulation, gamification, multiple forms of assessments (quantitative and qualitative), discovery learning, and a gamut of pedagogical and andragogical best practices.

7. Conclusion and Recommendations

The purpose of this quasi-experiment research was to answer two questions: (a) What is the effect of using the FETL Model in Mathematics lessons on student achievement? (b) What are the attitudes of students towards instruction in which the FETL Model is used? The results from quasi-experiment were statistically significant and corroborated findings outlined in the literature review section. The FETL Model was effective in increasing students' Mathematics scores controlling for their previous term Mathematics scores. The results of the Student Experience and Academic Engagement (SEAE) underscored the importance of incorporating artificial intelligence and other technologies (simulation and gamification), meaningful and relevant learning experiences, culturally and linguistically responsive pedagogy, innovative lesson planning frameworks, reflective practices, and the 4C's (Communication, Creativity, Critical Thinking, and Collaboration) at all levels of schooling including nursery, primary/elementary, secondary, and postsecondary. The results show that the FETL Model is a novel and innovative lesson planning and lesson delivery framework that is applicable across content areas and grade levels in K-12 classrooms and postsecondary classrooms. These findings have implications for educational policymakers, school administrators, practitioners, teacher training programs, curriculum and assessment developers, and other key stakeholders in education.

Based on the findings of this study and findings discussed in the literature review, the researcher makes the following recommendations to the Ministry of Education:

1. To effectively instruct the culturally and linguistically diverse students (rapidly growing emergent bilinguals and indigenous students), school leaders and teachers at all levels (nursery, primary, and secondary) must be trained continuously in culturally and linguistically responsive pedagogies.
2. Despite the gains made in equipping primary and secondary schools with information and communications technology (ICT), 100% of all schools (nursery, primary, secondary, and postsecondary) must be equipped with technology including smartboards, artificial intelligence technologies (assistive, adaptive, simulation, and gamification), and computer hardware (including Chromebooks, tablets, or iPad, projectors). Each class must have sufficient computers, so each student has access to one computer.
3. Training in technology must be subject and grade-level specific, so all teachers are receiving relevant and actionable training in technology to enhance their effectiveness by incorporating technology in instruction, learning activities, and assessments.
4. All nursery and primary schools should be assigned Mathematics instructional coaches to support teachers in preparing and delivering research-based Mathematics instruction, learning activities, and assessments. In addition, all schools at all levels must be supported with Special Education Teachers, Bilingual Teachers, English as a Second Language (ESL) teachers, and technology specialists.
5. To foster equity for all learners (special needs, gifted, indigenous, and emergent bilingual), all schools in Guyana (nursery, primary, and secondary) must be assigned trained and certified (Credentialed) Special Education Teachers, English as a Second Language (ESL) Teachers, Bilingual Teachers (English with Spanish or Tribal Languages), and Advanced Academics Teachers (Caribbean Advanced Proficiency Examination (CAPE) and Caribbean Secondary Education Certificate Examination (CSEC) Additional Mathematics) for secondary schools only.
6. To promote high impact Mathematics instruction, small group and individual intervention, assistive and adaptive technologies (such as Mathia and Khanmigo for Mathematics, natural language processing, speech-to-text, text-to-speech, Grammarly and other technologies) can be used for personalized instruction, intelligent tutoring, learning activities, and assessments. In addition, technologies such as Desmos, GeoGebra, and PheT Simulation can be used to build automaticity, fluency, and conceptual understanding by simulating abstract concepts in Mathematics.

7. Gamification software such as Kahoot! and Quizizz can be used to increase active engagement and stimulate interests in Mathematics classrooms.
8. Padlet, Canva, Google Apps (Docs, Sheets, Slides), and other collaborative software can be used to foster reflective practices for students and collaboration on group projects.

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Appendix A

Student Experience and Academic Engagement Instrument

Questionnaire ID: (Leave blank)

Gender: Male or Female (Circle your gender)

The following questions ask about your experience with the FETL Model that your teacher used to teach you in your classroom. Remember there is no right or wrong answer, just answer as accurately as possible by **circling the number that represents your answer**. Use the scale below to answer the questions.

The questionnaire consists of 17 items with a 5-point Likert scale including:

Strongly Disagree = 1

Disagree = 2

Neither Agree nor Disagree = 3

Agree = 4

Strongly Agree = 5

Variables	Item Statement	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
SEAE1	Technologies (like Smartboard, VR, Desmos, and PhET) make the instruction and learning activities engaging and enjoyable.	1	2	3	4	5
SEAE2	Technologies (like Smartboard, VR, Desmos, and PhET) make difficult concepts easier to understand.	1	2	3	4	5
SEAE3	I prefer lessons with technology over lessons that do not use technology.	1	2	3	4	5
SEAE4	Simulations and visualization using technologies (like Desmos VR, and PhET Simulations) help students to gain a deeper understanding of the concepts.	1	2	3	4	5
SEAE5	I participate fully in learning activities and pay attention when technology is used in the classroom.	1	2	3	4	5

Variables	Item Statement	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
SEAE6	I feel a sense of belonging in my classroom when my culture and traditions (such as Diwali, Mashramani, Emancipation Day, and Youman-Nabi) are used in instruction and learning activities.	1	2	3	4	5
SEAE7	Topics become meaningful when the teacher uses real-world examples and applications from my town/village, country, and from around the world.	1	2	3	4	5
SEAE8	I learn best when practical and role-playing activities are used in the classroom.	1	2	3	4	5
SEAE9	Topics become relevant and exciting when I can connect them to my career aspirations, current interests, identity, prior knowledge, and experiences.	1	2	3	4	5
SEAE10	I enjoy working in groups with my classmates.	1	2	3	4	5
SEAE11	I learn best when I am given opportunities to explain my understanding in writing and speaking.	1	2	3	4	5
SEAE12	I enjoy learning activities that are challenging and require deep thinking.	1	2	3	4	5
SEAE13	I enjoy opportunities where students can provide their own unique solutions to a problem.	1	2	3	4	5
SEAE14	I have fun and remember more when reviewing for tests using technologies like Kahoot! and Quizizz.	1	2	3	4	5
SEAE15	I prefer taking exams on the computer or tablet over paper exams.	1	2	3	4	5
SEAE16	I can demonstrate my knowledge and understanding of topics in other ways than just written tests.	1	2	3	4	5
SEAE17	Students should be given opportunities at the end of the lesson/lecture to reflect anonymously on their learning experiences and state what they understood well or did not understand and what they need further explanations on.	1	2	3	4	5

Appendix B

Postsecondary-1 Descriptive Statistics (%) of Data Collected by SEAE Instrument

Variable	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
Item 1	3.6	0.0	10.7	17.9	67.9
Item 2	7.1	3.6	14.3	46.4	28.6
Item 3	3.6	3.6	21.4	32.1	39.3
Item 4	3.6	0	3.6	60.7	32.1
Item 5	3.6	0	14.3	42.9	39.3
Item 6	7.1	3.6	32.1	32.1	25.0
Item 7	0	0	0	50.0	50.0
Item 8	3.6	0	7.1	39.3	50.0
Item 9	0	0	3.6	46.4	50.0
Item 10	14.3	3.6	46.4	17.9	17.9
Item 11	7.1	10.7	28.6	32.1	21.4
Item 12	10.7	14.3	25.0	28.6	21.4
Item 13	3.6	14.3	14.3	42.9	25.0
Item 14	3.6	0	7.1	14.3	75.0
Item 15	7.1	3.6	7.1	10.7	71.4
Item 16	7.1	0	14.3	28.6	50.0
Item 17	3.6	7.1	21.4	42.9	25.0

Appendix C

Postsecondary-2 Descriptive Statistics (%) of Data Collected by SEAE Instrument

Variable	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
Item 1	6.5	0.0	22.6	45.2	25.8
Item 2	3.2	38.7	22.6	22.6	12.9
Item 3	6.5	12.9	25.8	32.3	22.6
Item 4	3.2	6.5	22.6	48.4	19.4
Item 5	3.2	6.5	29.0	41.9	19.4
Item 6	3.2	9.7	25.8	45.2	16.1
Item 7	0	3.2	6.5	54.8	35.5
Item 8	3.2	12.9	9.7	45.2	29.0
Item 9	3.2	3.2	22.6	38.7	32.3
Item 10	19.4	25.8	41.9	6.5	6.5
Item 11	3.2	16.1	25.8	29.0	25.8
Item 12	3.2	9.7	48.4	32.3	6.5
Item 13	3.2	3.2	32.3	48.4	12.9
Item 14	6.5	3.2	9.7	35.5	45.2
Item 15	9.7	6.5	6.5	22.6	54.8
Item 16	3.2	9.7	19.4	22.6	45.2
Item 17	3.2	3.2	6.5	41.9	45.2

Appendix D

BHS Descriptive Statistics (%) of Data Collected by SEAE Instrument

Variable	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
Item 1	0.0	2.1	8.5	68.1	21.3
Item 2	12.8	21.3	8.5	29.8	27.7
Item 3	0.0	8.5	21.3	51.1	19.1
Item 4	0	0	8.5	63.8	27.5
Item 5	0	2.1	27.7	51.1	19.1
Item 6	2.1	4.3	27.7	46.8	19.1
Item 7	2.1	0.0	14.9	44.7	38.3
Item 8	4.3	19.1	31.9	25.5	19.1
Item 9	0.0	4.3	17.0	46.8	31.9
Item 10	4.3	12.8	17.0	27.7	38.3
Item 11	2.1	14.9	25.5	42.6	14.9
Item 12	6.4	14.9	23.4	40.4	14.9
Item 13	2.1	6.4	17.0	55.3	19.1
Item 14	2.1	4.3	6.4	29.8	57.4
Item 15	8.5	8.5	12.8	40.4	29.8
Item 16	2.1	2.1	23.4	44.7	27.7
Item 17	2.1	4.3	27.7	31.9	34.0

Appendix E

Postsecondary-2 Items Representing Technology Use, Meaningful and Relevant Learning, and 4C's

Items	Technology Use	4C's	Meaningful and Relevant Learning
Item 14	.782		
Item 15	.744		
Item 4	.739		
Item 3	.703		
Item 5	.673		
Item 1			
Item 11		.856	
Item 12		.754	
Item 13		.669	
Item 17		.621	
Item 10			
Item 8			.759
Item 7			.748
Item 9			.727
Item 16			
Item 2			
Item 6			

Note. The absolute value below was set to 0.60 for factorial analysis.

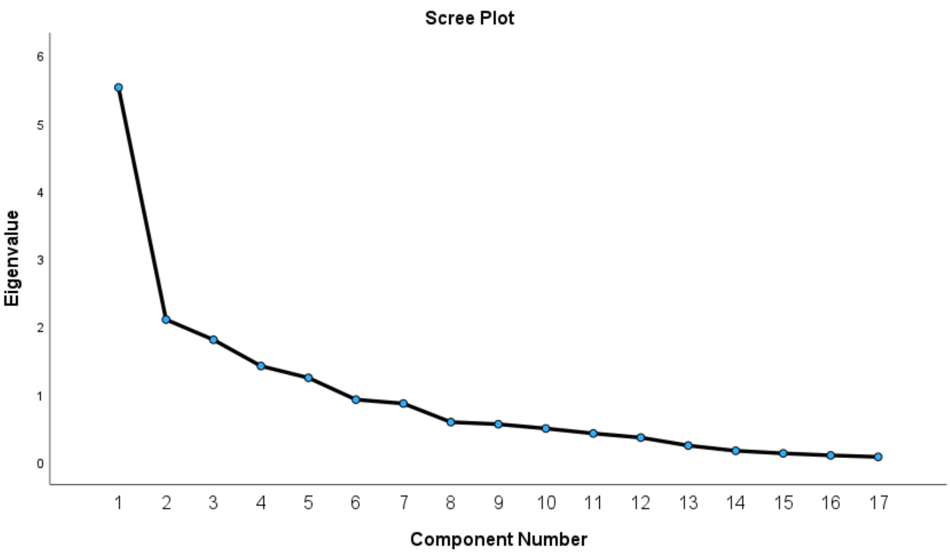

Figure 3. Scree plot for components of the instrument

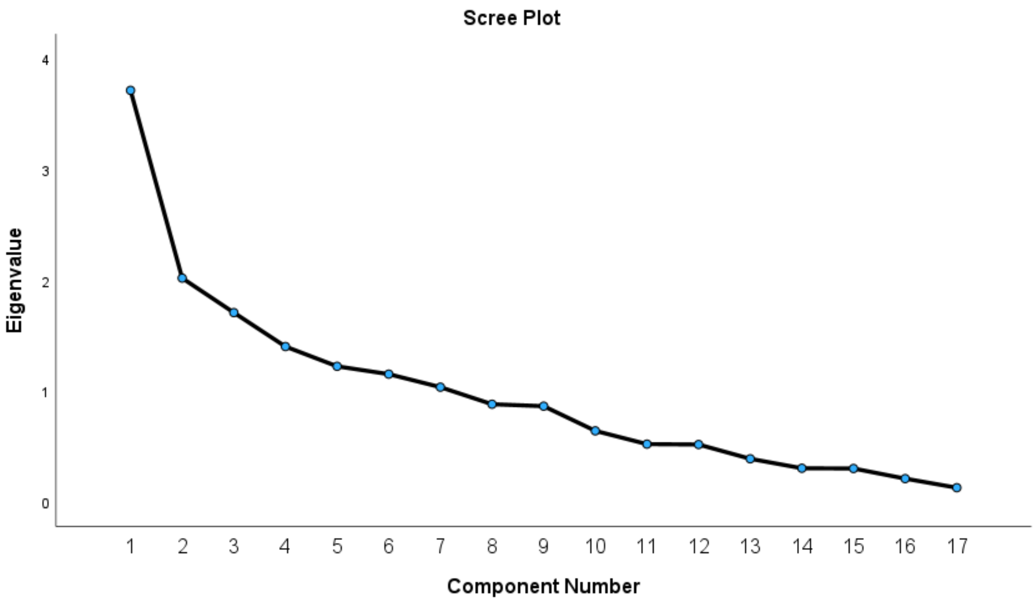

Figure 4. Scree plot for components of the instrument

Appendix F

Secondary School Items Representing Technology Use, Meaningful and Relevant Learning, and 4C's

Items	4C's	Meaningful and Relevant Learning	Technology Use
Item 17	.776		
Item 9	.749		
Item 10	.615		
Item 12	.606		
Item 8		.665	
Item 15		.614	
Item 6		.553	

Items	**4C's**	**Meaningful and Relevant Learning**	**Technology Use**
Item 7	.463	.531	
Item 11	.407	.514	
Item 13		.487	
Item 2			
Item 14			
Item 3			.775
Item 16			.662
Item 5			.586
Item 1			.541
Item 4			.435

Note. The absolute value below was set to 0.40 for factorial analysis.