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The Malaysian Digital Classroom Experiment: Quantifying the FF21A Module's Impact on Higher-Order Thinking

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Abstract: *The 21st century has witnessed astonishing transformation in the way the world functions, especially regarding the integration of technology in the educational landscape. Hence, in keeping with the goal of developing a highly educated populace, the educational system is currently under immense pressure to adapt to the digital age, aiming to produce graduates who can excel not only academically but also in their personal lives, professional careers, and employment. Therefore, the 21st century learning environment is receiving attention to achieve the goals of developed nations in Malaysia. A quasi-experimental research design was performed to examine the effects of the 21st century learning environment based on 21st Century Acculturation Module on 21st Century Skills and Academic Achievement (AA). The study included 120 form-four students who took Science subjects from secondary schools in Malaysia. Data analysis included means, standard deviations, independent sample T-test, and PLS-SEM. The result shows there were significant differences between the control group and the experimental group in terms of 21st Century Skills enhancement. Research findings also show a substantial difference in students AA between the experimental and control groups. The results gathered from PLS-SEM showed that the developed module moderates the Life and Career (LC) skills and AA relationships. It is evident that the module produced by the amalgamation of Dale's Cone of Experiences and Revised Bloom's Taxonomy Frameworks along with the use of technology in a Virtual Learning Environment (VLE) improved students' 21st Century Skills, and the students also performed better in AA.*

Keywords: *21st century pedagogy, 21st century skills, technology in education, higher order thinking skills.*

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Introduction

The implementation of the advanced technological revolution has significantly developed interconnected dependencies between the educational sector and the professional realm, which facilitated the adoption of advanced methodologies that were previously inaccessible. Malaysia saw a 5.1% rise in graduates from 5.63 million in 2021 to 5.92 million in 2022. According to the Department of Statistics Malaysia (DOSM), there were 591.9 thousand unemployed people in February 2023 - a 3.5 percent reduction from 2022. However, according to the Board of Engineers Malaysia (BEM), in 2022, the engineer-to-population ratio in Malaysia was 1:170, which is in contrast with developed countries like Germany and France have a ratio of 1:100. These statistics indicate a persistent high demand for engineers in Malaysia as it aims to attain the status of a technology-producing nation. These statistics indicate a persistent high demand for engineers in Malaysia as it aims to attain the status of a technology-producing nation.

The increasing prevalence of technology-producing nations has been accompanied by an increase in the pressure on educational institutions to produce high-quality graduates to meet high-skilled job demand. In line with emerging technologies and labor needs, education is evolving to the next level. The Malaysian Government's Digital Education Policy aims to strengthen the digital economy and improve national education quality. The Ministry of Education introduced ICT-based learning since 2014, but challenges persist. Malaysian Education Development Plan 2013-2025 outlined the shift towards providing equitable access to quality education on par with international standards by focusing on improving the quality of Science, Technology, Engineering, and Mathematics (STEM) education as the key priority. To successfully implement digitalization, educators must master both pedagogy and digital skills in teaching and learning processes, aligning with the latest Industrial Revolution. Hence, Malaysia is persistently striving to cultivate knowledgeable and skilled human capital by emphasizing the problem-solving approach to address the challenges and issues faced by the population by implementing Fourth Industrial Revolution (IR4.0) technologies that integrate the physical and digital realms. Consequently, 21st Century Skills have become a popular term in education. It is essential for the development of these skills to advance simultaneously with the latest technology, as both factors are vital in the present digital age.

The integration of STEM into a problem-solving approach in education is intricately related to efforts to cultivate higher order thinking skills such as analysis, evaluation and synthesis. among students. Both

approaches foster an active, collaborative learning environment and enhance students' cognitive abilities. While technology enables students to acquire knowledge and skills related to 21st Century Skills, such as quick decision-making, problem-solving, and critical thinking, which are prominent in the 21st century (Vaan Laar et al., 2020). An effective teaching and learning approach need to be implemented to produce students with 21st century skills and the ability to achieve higher order thinking skills (HOTs) in their learning. Therefore, as technology becomes a crucial tool for tailoring teaching methods and customizing the educational process to suit the qualities and requirements of each student, it is compulsory to design a strategic learning environment on how to use technology as an effective tool in the teaching and learning process to boost students' 21st Century Skills and HOTs.

Background

The global scoping review covering 94 studies conducted by Hague (2024) finds blended and flipped learning approaches to be the ones which hold the greatest promise in fostering HOTS such as critical thinking and creativity in higher online education, and, more often than not, achieve better results than purely online or fully face-to-face learning formats. Major contributing factors appear to be student-centered interactive pedagogy (such as scaffolded project-based learning or Socratic questioning in discussions) and structured faculty presence through mechanisms such as feedback and facilitation. However, large potential equity gaps exist as online learning tends to exacerbate the disadvantages of underprepared and marginalized students who do not have equal access and self-regulation. A critical gap still prevails in creativity-based studies (only about 10% of the studies), longitudinal reconnaissance and studies in non-Western contexts, where there is an underrepresentation of Southeast Asian nations like Malaysia. To tap the potential of online learning for HOTS, the OECD calls for tailored pedagogics training and equity-centered design (Hague, 2024; Yu et al., 2021; Xu & Jaggars, 2014). The application of blended learning models in terms of HOTS demonstrates enormous diversity all over the world. Blended approaches show a lot of promise (Hague, 2024), but South Korea combines the use of AI-powered LMS analytics inclusion to personalize HOTS tasks (Bonk & Wiley, 2020), while Scandinavia focuses on students co-creating learning materials in the digital environment (Pinheiro et al., 2023). In contrast to Malaysia's VLE focus as highlighted, such innovations can be scaled up even as multisensory engagement is noted.

The Organization for Economic Co-operation and Development (OECD) has initiated the Future of Education and Skills 2030 framework in

2018 to tackle the challenge of students' success in the context of Industrial Revolution 5.0. The OECD helps education systems identify the information, skills, attitudes, and values necessary for learners to succeed in the 21st century. The framework identifies the competencies that learners need, including cognitive and metacognitive skills such as critical and creative thinking, adaptability in learning and self-regulation; equally important social and emotional skills such as empathy, self-efficacy and teamwork; as well as practical skills and physical skills such as competent interaction, evolving information, and communication technologies (OECD, 2019, 2023).

To cope with the rapid changes in Industry 4.0, the Malaysian government has established the implementation of the Digital Education Policy as the government's effort to strengthen the digital economy as well as enhance the quality of national education. The Malaysian Education Development Plan 2013-2025 outlined the shift towards providing equitable access to quality education on par with international standards by focusing on improving the quality of Science, Technology, Engineering, and Mathematics (STEM) education as the key priority. Therefore, achieving this aspiration requires equipping graduates with skills that align with the latest Industrial Revolution. STEM focuses on practical learning to allow students to experience real-world applications of knowledge. It is also an effort to foster creativity, innovation, critical thinking and problem-solving skills. The importance of STEM education is widely recognized as being essential to Malaysia's goals of becoming a high-income, innovation-led country (Idris et al., 2023). However, educators and students continue to face various constraints and challenges (Darus et al., 2023; Diana, 2021). This situation give a great impact on the implementation of STEM in teaching and learning process. Reports indicate that integrating STEM into pedagogy presents various issues and challenges (Ibrahim et al., 2024; Markus et al., 2021). The issues must be properly addressed to ensure the successful implementation of digitalization in education. Educators must master not only pedagogy but also digital skills in the teaching and learning process.

The efficient approach to adapting technology into the classroom is still unclear, and most educators are still figuring out how to adopt technology effectively and meaningfully in their teaching practice. Solely integrating technology into pedagogy will not heighten the effectiveness of learning. This is mainly caused by the process of success requiring continuous professional development for educators, school administrators, and other educational staff (Muhammad & Noor Ibrahim, 2022; Abu Talib et al., 2025). Thus, for technology to be effectively utilized in the classroom, it needs to be combined with other teaching methods that actively engage students and consider the

cognitive abilities of the human brain. Hence, educators must acknowledge the necessity to revise and reconsider pedagogy, considering the transformations brought about by the digital age (McDiarmid & Zhao, 2023; Tsibulnikova, 2022). Educators should avoid exclusively implementing specific teaching and learning methodologies and instead adapt to the present learning environment. Nevertheless, educators' eagerness to utilize digital tools has occasionally overtaken consideration of their pedagogical benefits (Fossland & Tømte, 2020). To support 21st century learners, technology integration, and the development of 21st Century Skills, it is crucial to revolutionize the approaches in teaching and learning, leveraging technological innovations, to ensure the development of a competent generation that possesses global proficiency. Hence, the purpose of this study is to investigate how the use of the amalgamation of active learning and problem-based learning environments along with technology usage can cultivate students' 21st Century Skills and HOTs in terms of academic achievement.

Global educators in 21st century learning environments

The 21st Century has redefined physical learning spaces, emphasizing technologies that allow hybrid education. Digital tools dissolve geographical barriers, allowing for collaboration and co-creation of content across the world, fundamentally redefined educational boundaries (Ab Liah et al., 2023). All this needs a change in pedagogy and teaching-learning processes: the teacher will adopt student-centered-, social learning-and technology-integrated ways of teaching to accommodate different intelligences (Kim How et al., 2022). Thus, the effective learning environments combined collaborative work, discussions, experiments, and digital using as specified in lesson objectives to improve the results.

While technology races on, Revised Bloom's Taxonomy will remain relevant in scaffolding cognitive advancement from the mere foundational knowledge and higher-order analysis. Intensified technology adoption in Malaysiais to develop global competence through higher-order thinking skills (HOTS) formulated in the Malaysia Education Blueprint (2013-2025). PISA (2022) results, however, indicate falling performance in the country, which has been blamed on a negative design in the curricula. Studies indicate that this is a scribe to a continued teacher-centered paradigm rooted in limited HOTS knowledge of the teachers which contradicts the policy directives (Ab Liah et al., 2023; Kim How et al., 2022). Pedagogical upskilling coupled with frameworks like Dale's Cone of Experience for multisensory learning must take action immediately to correct this problem. It is evident from Dale's

model that involving multiple senses in a cognitive process hastens the retention of knowledge than text-based learning (Subramony, 2003).

Technology integration is really seldom aligned with theory. Dale's Cone is not being examined enough in terms of its applicability to digital contexts according to Subramony (2003). However, recently, new and emerging technologies deliver immersion experiences. Nothing is worse than having a technology-rich environment without pedagogical intentionality. This misalignment between the digital tools and the aims of instruction has an adverse effect on students' academic achievement. Research concurs with the fact that educators face challenges in choosing the right methodologies to cultivate HOTS and 21st-century skills among students, thus resulting in inconsistent student progression (Marouli, 2021). The core of the problem lies in the ill-matched educational objectives. According to Marouli (2021), a standardized assessment system inhibits experiential learning and problem-solving, thereby limiting educators' ability to leverage technology's potential. Thus, this mismatch is an obstacle to the 21st- Century Education that needs to be provided by an institution, innovative teaching, and a cultural shift. Educators need to fill gaps between theory and practice by showing content relevance to the technology-driven realities of society. Their role changes to being pedagogical mediators who connect learners with real-world applications through horizon-expanding instruction. This would require mastery of technology-integrated environments at the same time advancing curriculum objectives, HOTS, and 21st-century competencies.

Research questions & hypotheses

The research examines the effectiveness of an innovative model, FF21A, in technology-mediated learning involving Dale's cone of experience and Revised Bloom's taxonomy for students' 21st-century skills, namely Learning and Innovation [LI], Information/Media/Technology [IMT], Life/Career [LC], and Academic Achievements [AA].

RQ1: Does the FF21A Module improve 21st-century skills (LI, IMT, LC) and academic achievement (AA) compared to conventional teaching methods?

RQ2: Does the FF21A Module moderate the relationship between 21st-century skills and academic achievement?

This study has hypothesized a series of statements to assess the functioning of the FF21A Module in developing 21st-century skills and academic achievement (AA). The hypotheses are classified under the three main headings: within-group improvements, between-group differences, and the moderating effects of the intervention (table 1).

A. Within-Group Improvements (Pre- vs. Post-Intervention)

The first set of hypotheses (H1a-H4a and H1b-H4b) pertains to the changes within one group or the other from intervention onset to post-intervention:

a. H1a-H4a: Whereas the control group taught the conventional way was expected to improve considerably on LI, IMT skills, LC, and AA.

b. H1b-H4b: The experimental group using the FF21A Module was hypothesized to improve even more on all of these LI, IMT, LC, and AA after the intervention.

B. Between-Group Differences (Control vs. Experimental)

Second, the H1s treatment model (H1c-H4c and H1d-H4d) is looking at differences between the two groups-control and experimental-at baseline and after intervention:

a. H1c-H4c: The null hypotheses concern whether the two groups were statistically equivalent at the pre-assessment stage for each of the variables, i.e., LI, IMT, LC, and AA.

b. H1d-H4d: An exploration of whether after the intervention the experimental group has outperformed the control group on the same four measures using the data from post-assessment.

C. Moderating Effects of the FF21A Module

The last of the hypotheses (H5-H7) deals with the possibility that the FF21A Module is a moderator in the relationship between certain 21st-century skills and academic achievement:

a. H5: The FF21A Module acts as a moderator for life intelligence (LI) and academic achievement (AA).

b. H6: The FF21A Module acts as a moderator for information and media technology (IMT) skills and academic achievement (AA).

c. H7: The FF21A Module acts as a moderator for life and career skills (LC) and academic achievement (AA).

Table 1. Hypotheses summary

Hypothesis	Relationship Tested	Statistical Test	Result
H1a–H4a	Control group pre-post improvements	Paired t-test	All supported
H1b–H4b	Experimental group pre-post gains	Paired t-test	All supported
H1c–H4c	Baseline equivalence between groups	Independent t-test	Partial support
H1d–H4d	Post-intervention group differences	Independent t-test	All supported
H5–H7	FF21A's moderating effect on AA	PLS-SEM with bootstrapping	Only H7 supported

Source: Researcher's own conception

Methodology

This study was conducted to identify the effects of the amalgamation of Dale's Cone of Experience and Revised Bloom's Taxonomy along with technology usage in a Virtual Learning Environment (VLE) embedded in the 21st Century Acculturation Module on students' 21st Century Skills and Higher Order Thinking Skills (HOTs) using a quasi-experimental methodology, utilizing non-equivalent groups for pre-test and post-test. The module was developed by using student-centered approaches, social learning approaches and technology usage in the teaching and learning process. Besides, different methods and activities for students with diverse intelligence also embedded in the module such as collaborative work, discussions, teamwork, experiments, presentations and technological utilization. The objective was to investigate the effect of the 21st Century Acculturation module on 21st Century Skills (Learning and Innovation, Information, Media and Technology and Life and Career) and the Academic Achievement test which constructed by using HOTs questionson 120 Form 4 students studying Science in secondary schools in Selangor and Perak. The module was constructed by using the amalgamation of Dale's Cone of Experience, Revised Bloom's Taxonomy, and the Virtual Learning Environment teaching and learning approach. Table 2 presents a visual representation of the pre-test (labeled as 1) and post-test (labeled as 2) for the group design.

The FF21A teaching module contained three pedagogical foundations: Dale's Cone of Experience (multi-sensory participation), the Revised Bloom's Taxonomy (cognitive progression), and the VLE tools (collaborative technology). Activities were designed to align explicitly with theoretical tiers; for example, simulations → Contrived Experiences; debates → Evaluating (table 2).

Table 2: FF21A Module Components and Theoretical Alignment

Module Phase	Dale's Cone Tier	Bloom's Level	Sample VLE Activity
Problem Launch	Abstract Symbols	Remember/Understand	Video case analysis + quiz
Collaborative Task	Dramatized Experience	Apply/Analyze	Role-play negotiation forum
Simulation Lab	Contrived Experience	Evaluate	Physics simulation + data debate
Project Creation	Direct Purposeful Experience	Create	Design prototype (3D modeling tool)

Source: Researchers' own conception

The experimental treatment group also had to follow a 3-day compulsory workshop on (1) facilitation towards student-centered instruction, (2) navigation through a VLE and (3) module customization. The fidelity checklist throughout the 14-week intervention made sure that the FF21A module was delivered in a consistent and high-quality manner. This included confirming 3-day workshop teacher training, ensuring all students had access to the VLE and checking that the lesson plans were contextually modified. Each week, the four core areas included student engagement with collaborative VLE activities (≥80%) simulating experiments with data

analysis; students reflect using higher-order thinking—Bloom's Evaluate/Create—at least two VLE tools used each session. Quality control thresholds were set at ≥70% participation in the VLE, weekly alignment with three or more sensory tiers from Dale's Cone, and teacher turnaround time for feedback within 24 hours. The researchers validated implementation biweekly through VLE analytics, observation of 20% of sessions using a student-centered rubric, and student satisfaction surveys. Fidelity was calculated as: (Number of "Yes" responses / 12 items) × 100%, with ≥85% classified as high fidelity. A digital analytics dashboard underpinning, followed guidance from a student-centered observation rubric, allowed the team to explore this.

Fidelity in implementation was systematically kept by a 12-item checklist as it marked out the conformity to the core elements weekly on which were, for instance, ≥80% student engagement in collaborative tasks, timely feedback. Compliance was determined biweekly (fidelity score = [Yes responses/12] × 100%), and thresholds for intervention (<70%) and high adherence (≥85%) were set before. Triangulation through VLE analytics, random classroom observation the randomization of about 20 percent sessions, and teacher self-reports ensured ecological validity.

Table 3. Graphical depiction of the pre-test (indicated as 1) and post-test (indicated as 2) of group design; where a = 21st Century Skills Acculturation questionnaire; b = Performance Test.

	Pre-test	**Independent Variable**	**Post-test**
Experimental Group	Oa1, b1	X_{Module}	Oa2, b2
Control Group	Oa1, b1	$X_{Conventional}$	Oa2, b2

Source: Results of the data analysis (findings)

Research procedure

The experiment was conducted in two different situations described as follows: (1) presence of module (indicated as XModule), and (2) absence of module (indicated as XConventional). Furthermore, the current experiment incorporates the 21st Century Acculturation Module as independent variables, which are moderated by teaching approaches that are traditional, and module based. While the dependent variable refers to 21st Century Skills Acculturation and Performance Test (Academic Achievement). The moderating variable for the current research is the use of the developed module for the experimental group and the use of conventional teaching and learning for the control group before and after the intervention. Therefore, the moderating variable refers to

the timeline of the intervention for the two groups of students: the control and the experimental group.

Both groups were observed for four weeks using a pre-test before conducting the research (shown as O). The pre-test included the questionnaire on 21st Century Skills acculturation (marked as a1) and Academic Achievement (marked as b1). Both groups were exposed to two different teaching and learning methods (marked as X) for fourteen weeks. Students in experimental groups (indicated as XModule) used the developed module which is technology-based learning approaches, while the traditional teaching and learning process was adopted by control group (indicated as XConventional). Both groups involved in this research were subjected to a post-test (similar instruments as to the pre-test) in the final analysis of the fourteen-week experiment. The post-test consists of a 21st Century Skills Acculturation questionnaire (labeled as a2) and Performance Test (indicated as b2). It is important to note that both groups received the same teaching materials as well as the same amount of time during the teaching and learning process. On another note, a module on how to conduct the teaching and learning process for the experimental group was constructed and then introduced to the teacher to ensure that the process can be performed well.

Results & Generalizations

Table 4. Paired T-Test Results (Experimental Group)

Variable	Pre-Mean	Post-Mean	t-value	p-value
LI	61.75	68.75	-8.390	0.000
IMT	34.93	48.27	-13.878	0.000
LC	47.93	58.02	-7.809	0.000
AA	29.13	70.40	-15.071	0.000

Source: Results of the data analysis (findings)

The statistical analyses depict significant improvement in 21st-century learning skills and in academic achievement (AA) in both groups. The paired t-test shows remarkable improvement within groups after intervention as shown in Table4. For the experimental group, Learning and Innovation (LI: t= -8.390, p< 0.001), Information, Media and Technology (IMT: t= -13.878, p< 0.001), Life and Career (LC: t = -7.809, p< 0.001) and Academic Achievement (AA: t = -15.071, p< 0.001) have shown significant improvements in favor of FF21A modules, known for using technology-based collaborative pedagogy. The control group used the conventional approach but improved with smaller effect sizes (LI: Δ +2.03; AA: Δ +18.55). The small improvements might signify baseline pedagogical effectiveness.

Independent t-tests further highlighted stark disparities between groups post-intervention (Table 5). The experimental group greatly outperformed the control group on LI (t = -12.649, p< 0.001; Cohen's d= 1.8), IMT (t= -45.745, p< 0.001; d= 2.1), LC (t= -52.590, p< 0.001d = 2.4), and AA (t = -12.700, p< 0.001; d= 1.7). These large effect sizes (d> 0.8) demonstrate the superior capacity of FF21A modules to improve 21st-century competencies and academic achievements relative to conventional modalities. The differences found in IMT and LC skills-those clearly related to digital literacy and collaborative problem solving-reflect the module's correspondence with Dale's Cone of Experience and Virtual Learning Environment (VLE) frameworks, which stress multisensory engagement and real-world applications.

Mean implementation fidelity across experimental groups was 89% (SD = 4.2), with no session having fidelity falling below the 85% threshold. This indicates that teachers were most adherent for collaborative task facilitation (96%); for VLE tool usage, adherence was 92%. Minor adjustments needed in 18% of sessions in simulation labs due to variation in connectivity were time adjustments; however, all other constraints of fidelity remained in place. The structural alignment of activities with Dale-Bloom frameworks (table 2) and ongoing fidelity monitoring underpinned the ecological validity of the intervention. To precisely ascertain the effects, a data filtration process was used to compare the 21st Century Skills and Academic Achievement of students who utilized the 21st Century Acculturation Module to those who did not. The result in Table 5 shows that the independent sample t-test for Learning and Innovation (LI), Information, Media and Technology (IMT), Life and Career (LC), and Academic Achievement (AA).

Table 5. Independent sample t-test results in post-assessment.

Variables	Assessment	Mean	T	*P*	Cohen's *d*
LI	Control	64.2833	-12.649	0.000	
	Experimental	68.7500			1.8
IMT	Control	32.0833	-45.745	0.000	
	Experimental	48.2667			2.1
LC	Control	48.9000	-52.590	0.000	
	Experimental	58.0167			2.4
AA	Control	50.08	-12.700	0.000	
	Experimental	70.40			1.7

Note:Cohen's *d* thresholds: Small (0.2), Medium (0.5), Large (0.8) (Cohen, 1988).
Source: Results of the data analysis (findings)

Based on Table 5. It can be concluded that:

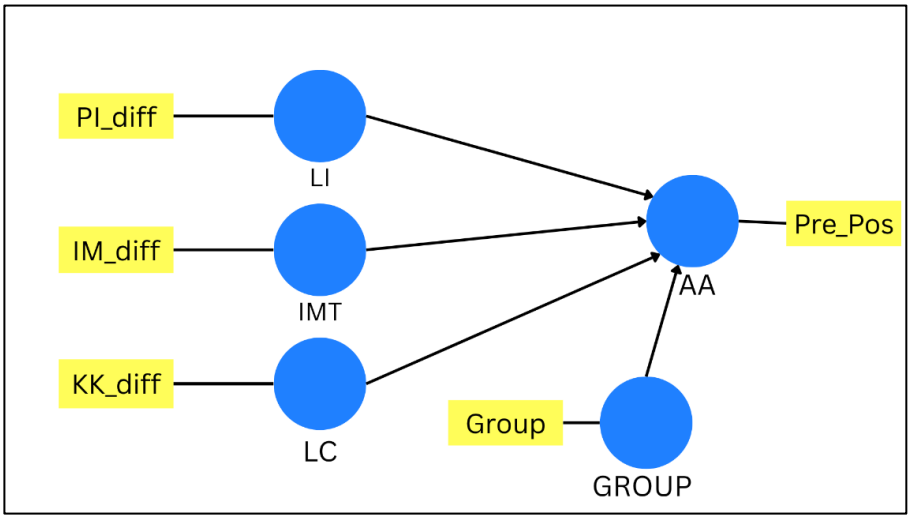
i. For Learning and Innovation (LI), the mean difference between the control and experimental group was significant (t=-12.649, p=0.000) in the post-assessment.
ii. For Information, Media and Technology (IMT), the mean difference between the control and experimental group was significant (t=-45.745, p=0.000) in the post-assessment.
iii. For Life and Career (LC), the mean difference between the control and experimental group was significant (t=-52.590, p=0.000) in the post-assessment.
iv. For Academic Achievement (AA), the result shows that the mean difference between the control and experimental group was significant (t=-12.700, p=0.000) in the post-assessment.

As a result of using the developed module, the students in the experimental group showed improvement in skills development (i.e. learning and innovation skills (LI), information, media, and technology skills (IMT) and life and career skills (LC)) better than the students in the control group. This showed that by using the 21st century learning environment in the teaching and learning process, as embedded in the module, students improved their LI, IMT and LC skills. Students in the experimental group utilized technology-based, student-centered, and social learning approaches in their learning process. The teachers act as facilitators and help the students to strengthen their knowledge and boost their 21st century skills. Students in the experimental group actively engaged in group work through discussion, presentation, and collaboration. These activities practiced by the students effectively improved their skills. This is in line with research from Chu et al. (2021), Gürsoy (2021), Saad & Zainudin (2022) and Timotheou et al. (2023) on the effect of technology usage in teaching and learning process along with suitable learning approaches and guidance especially on the development of skills.

Regarding Academic Achievement, students in the experimental group outperformed students in the control group. This demonstrated that students could acquire Higher Order Thinking Skills (HOTs) more successfully than those in the control group when they used the 21st century learning environment as described in the module. Adapting technology into the classroom along with the appropriate teaching and learning environment able to boost students' thinking skills and score better in their performance test. The test was carefully constructed by using different levels of difficulty

based on cognitive levels in Revised Bloom's Taxonomy. The ability of the students in the experimental group to answer high-level questions in the test shows that the learning environment and the approaches used in the teaching and learning process play a significant role in supporting students' cognitive development. This finding aligns with the previous studies conducted by researchers namely Wannapiroon & Pimdee (2022), Liu & Zhang (2022), and Kliziene et al. (2021). Therefore, the research findings demonstrated that the suggested 21st century learning as embedded in the developed module recommends a modern learning environment is suitable for students to fully enhance their cognitive abilities and foster the development of their 21st Century Skills. The moderating effect of the module's use on the relationship between the three domains of the 21st Century Skills (LI, IMT & LC) and Academic Achievement (AA) as in Table 4 was tested using the PLS-SEM approach (Fig. 1). Partial Least Squares Structural Equation Modeling (PLS-SEM) examined the moderating role of the FF21A module between 21st-century skills and academic achievement. PLS-SEM is a powerful multivariate modeling procedure that is exploratory, complex, and suitable for small sample sizes; sometimes, it obtains better predictive performance than strict adherence to the normality assumptions of data (Hair et al., 2022). Proceeding in this way meets the aims of the research project in which the FF21A module was evaluated on the interplay between Learning and Innovation (LI), Information, Media and Technology (IMT), Life and Career (LC) skills, and Academic Achievement (AA).

Figure 1. The Structural Model in PLS-SEM Analysis



Source: Results of the data analysis (findings)

Table 6. Result of the moderating effect analysis.

Path	Path Coefficient β	TStatistics	*p*Values	Decision
H1: LI*Group→AA	-0.268	0.130	< 0.05	Supported
H2: IMT*Group →AA	-0.108	0.522	< 0.05	Supported
H3: LC*Group→AA	0.583	0.004	< 0.05	NotSupported

Note: Significance threshold: *p* < 0.05. LI = Learning and Innovation; IMT = Information, Media, and Technology; LC = Life and Career; AA = Academic Achievement.
Source: Results of the data analysis (findings)

Table 7. Result of the Moderating Effect Analysis

Hypothesis	Path	Path Coefficient, β	T Statistics	*p* Values	Decision
H5: LI*Group → AA		-0.268	1.513	0.130	Not supported
H6: IMT*Group → AA		-0.108	0.641	0.522	Not supported
H7: LC*Group → AA		0.583	2.875	0.004	Supported

Source: Results of the data analysis (findings)

After processing the model using SmartPLS 3.2.8, the output was subjected to bootstrapping with 5,000 subsamples to establish the level of significance of their effects on moderation. A total of three interaction terms - LI×Group, IMT×Group, and LC×Group - made up the structural model (Fig. 1), wherein the term "Group" represented the experimental (module-based) and control (conventional) conditions. The model validity checks - for collinearity (VIF < 5) and significance testing (p< 0.05) - constituted ensuring the validity of the model. The results of PLS-SEM analysis (Table 6) indicate that the FF21A module was a significant moderator of the relationship between LC skills and AA ($\beta = 0.583$, $t = 2.875$, $p = 0.004$). Interpreted in practical terms, it means that those exposed to the module had well-formed links between LC skills (for instance, teamwork, being adaptable) and academic success. The module, however, did not moderate the relationship between LI -AA ($\beta = -0.268$, $p = 0.130$) and IMT-AA ($\beta = -0.108$, $p = 0.522$). As noted earlier, the significant moderating effect of LC skills conforms with the social constructivist theory (Vygotsky, 1978), which considers learning in a group to make a difference in the cognitive development among students. Discussions, role-playing, and peer interactions in a Virtual Learning Environment (VLE) design within the module would lead to the practical application of LC skills toward better performance in academics (Chu et al., 2021). On the contrary, LI and IMT skills that underscore individual creativity and technical proficiency may need some time or appropriate scaffolding to be converted into tangible benefits in academic performance, according to social cognitive theory

(Bandura, 1986). These display the moderating effects more aptly revealing that students in the experimental group with strong LC skills achieved disproportionate leaps in academic performance compared with the control group. This makes clear the module's effectiveness with stimuli through cooperative, learner-centered pedagogies that ultimately heighten student learning results. As a result of the above analysis PLS-SEM, it can be said that the FF21A module had some specific influences on LC skills so that educators could now be informed on how to design collaborative and career-ready learning in technology-enhanced environments. Longitudinal designs for future research should be employed to study the sustainability of these effects and to adapt the module for various cultural and infrastructural contexts (table 5).

The study indicated that the FF21A module moderated the relationship between LC skill and academic achievement AA, whereas such an effect was not there under LI or IMT skills. This differentiation can be explained using social constructivist theory (Vygotsky, 1978), which believes that learning will stimulate cognitive growth among peers by their meeting for problems based on solving and sharing in this learning environment. Collaborating within the LC domain is teamwork, and flexibility and career readiness are some of the close alignment principles with what the module was up to or designed with—group discussions, presentations, and role-playing activities in a virtual learning environment (VLE). It stands to reason that these are the activities that deepen cognitive engagement because it requires the negotiation of ideas and the co-construction of knowledge (Chu et al, 2021), thereby strengthening the LCAA relationship. LI and IMT skills feature technical aptitude and individual creativity and as such potentially require more personalized or perhaps long-term practice before contributing to academic success. The module, for instance, encouraged innovation with the use of technology but within the 14 interventions, a period deemed insufficient for students to develop a firm grasp of such skills. According to Bandura's social cognitive theory (1986), this is demonstrated by the long periods of practice and reinforcement necessary for perfect mastery of a skill. An appropriate step in this regard with the ongoing developments in the module may be to incorporate adaptive feedback mechanisms for LI/IMT skills, as recommended by Liu & Zhang (2022).

The hypothesis may be evaluated systematically through quantitative analysis, and this is expected to yield insights into the effectiveness of the FF21A module. For within-group improvements (H1a-H4a and H1b-H4b), both the control and experimental groups showed very significant pre-post gains in each of the variables (LI, IMT, LC, AA), measured with the use of paired t-tests (Table 4). However, the size of effects in the experimental group was considerably larger

(e.g., AA: Δ +41.27 vs. Δ +18.55 in the control group), highlighting the module's higher potential for enhancing 21st-century skills and academic achievement. This distinguishes the module's inclination towards Dale's Cone of Experience and VLE frameworks, which are clearly multisensory, collaborative ease, and the learning strategy used in showing ordinary learning experience (Chu et al., 2021) compared to traditional methods. The minor gains made by the control group possibly indicate teaching effectiveness from a baseline but show the constraints that teacher-centered strategies place on attempts to elicit higher-order thinking. For between-group differences (H1c-H4c and H1d-H4d), independent t-tests disclosed partial baseline equivalence (H1c-H4c); this means that primary differences were not so significant that the validity of the study was challenged. After the experimental intervention, this group outperformed control participants in media measures (H1d-H4d) and varied effect sizes according to Cohen's *d* which were greater than 1.7 (Table 5). Particularly noticeable are the differences in IMT (d=2.1) and LC (d=2.4) depending directly on what the module targets; that is, digital literacy and collaboration in the problem-solving process-which inherently relates to Dale's framework of experiential learning. All these findings further corroborate previous studies (Wannapiroon & Pimdee, 2022) confirming that the technology-mediated student-centered environment creates better technical proficiency and social competence. The hypotheses regarding the moderating effects (H5-H7) produced mixed results that are summarized in Tables 6 and 7. The analysis of PLS-SEM (Table 6) established that the module FF21A significantly moderated the relationship between Life and Career (LC) skills and Academic Attainment (AA). This is represented by H7: $\beta = 0.583$, $t = 2.875$, $p = 0.004$. This finding is in line with the structural model (Fig. 1) and social constructivist theory (Vygotsky, 1978), wherein, as a type of collaborative activities such as group discussion and role-playing, strengthened LC skills (e.g., teamwork, adaptability) through peer-mediated knowledge construction (Chu et al., 2021), resulting in direct improvement of academic performance. On the contrary, Learning and Innovation (LI) and Information, Media, and Technology (IMT) skills did not exhibit any credibility regarding moderation effects (H5: $\beta = -0.268$, $p = 0.130$ and H6: $\beta = -0.108$, $p = 0.522$). These nonsignificant results (Table 7) imply that LI (individual creativity) and IMT (technical proficiency) could entail extended intervention periods or scaffolding feedback systems before their effects become observable in students' academic performance, as Bandura (1986) hypothesized through his social cognitive theory. It shows a clear juxtaposition as posited by H7 against H5/H6. It denotes the immediate success of the module in building collaborative aligned competencies for a career yet poses limitations on the aspect of individual-based or intensive technical skills, all in a span of just 14 weeks.

Discussion

The findings expose deep-rooted tensions between pedagogical intention and contextual reality. FF21A module had non-significant moderation on pathways LI→AA (β = -0.268, p = 0.130) and IMT→AA (β = -0.108, p = 0.522). While collaborative virtual tasks were meant to enhance teamwork and adaptability consistent with the STEAM framework posited by Wannapiroon & Pimdee (2022), the 14-week length of the intervention provided little scaffolding for nurturing individual creativity (LI) and mastering the technical skills (IMT). This limitation in the timing itself violates Kliziene et al.'s (2021) empirical proofs that technology-mediated cognitive gains require 6 to 12 months to consolidate. The situation becomes more unambiguous in the Malaysian context, under the teacher-centric atmosphere (Kim How et al., 2022), where teachers actively inhibit any creative conditioning through subtle culture-based hierarchies. Consequently, FF21A—a student-centered design—became diverging epistemologically from local pedagogical norms; an unguided intervention-level defect. Bandura's (1986) reinforcement theory provides an explanation: In the absence of lengthy cycles of iterative practice and feedback, skills are transformed into procedures rather than transformations. This absence of Liu & Zhang's (2022) adaptive analytics, however, forfeited the much-needed real-time scaffolding for LI/IMT internalization. This realization presents the aforementioned OECD equity warnings (Hague, 2024): without properly differentiated support, interventions entirely marginalize unprepared learners. Consequently, FF21A instead reinforced extreme inequities to be challenged.

Under this technology-mediated scenario, the experimental group was said to put instructors in a facilitating role in the Ong & Quek (2023) sense of facilitating higher online engagement. However, McDiarmid & Zhao (2023) point to an inadvertent methodological problem: the instructors' enthusiasms for innovative interventions could potentially confer a performance bias and inflate collaborative results, blinding them from recognizing shortfalls in individual LI/IMT competencies. This contradiction presents a more serious tension: The collaborative tasks could very well foster an illusion of skill acquisition, while in fact not developing any metacognitive underpinnings for reasoning in creativity and technical proficiency. This impression is substantiated by Noroozi et al. (2023), who reported that there were major mismatches between students' self-perceived HOTS mastery of the constructs and their actual competent performances, a flaw upon which FF21A relied in gauging so-called metrics of engagement. Idris et al. (2023) recognized the rural-urban divide in Malaysia as a factor of digital access—90.8% Malay vs.

9.2% minority representation in this study. Accordingly, it seems that FF21A's simulation-centered design offered distinct advantages for urban participants, thereby running contrary to Hague's (2024) equity imperative. Meanwhile, the rural disadvantaged faced worst conditions since they had to contend with poor infrastructure and a culturally alien task that required pupils to shed innovation as model Kim How et al. (2022) described authority-chained pedagogies. Thus, this collaborative framework gained an unfortunate potential for enhancing socioeconomic disparities.

With instructor bias (McDiarmid & Zhao, 2023) and urban sampling bias (Idris et al., 2023) uncontrolled in the quasi-experimental design, generalizability suffers. FF21A showed some short-term advantages in collaborative skills, but Kliziene et al.'s (2021) longitudinal evidence questions the durability of such outcomes for a mere 14 weeks. In addition, the absence of a multi-method assessment (Noroozi et al., 2023) created sizeable gaps: The absence of behavioral verification of IMT skill transfer and metrics for individual creative output beyond group deliverables. Four imperatives emerge for future iterations: align intervention length with Kliziene et al.'s (2021) 6-12 months threshold for sustainable gains, incorporate Yu et al.'s (2021) equity-centered frameworks, modify tasks to lend authority-adjacent pedagogy while gradually scaffolding autonomy, embed Liu & Zhang's (2022) AI-driven analytics to provide real-time scaffolding for LI/IMT and partner with policymakers to address Idris et al.'s (2023) documented rural bandwidth deficits.

The larger FF21A social project has failed for two primary reasons: contextual insensitivity and temporal naivete. The student-centered approach was based on an assumption of cultural readiness that is antithetic to the Malaysian pedagogical context (Kim How et al., 2022), and the shortened time frame did not engage the cognitive principles of consolidation (Kliziene et al., 2021). The next generation will be politically engaged design (Yu et al., 2021), one that acts against infrastructural inequities (Idris et al., 2023) as much as it raises skills. Without this integration, it will run contrary to reasons that technological innovations are apt to bridge divides—just as Hague (2024) cautions in the OECD's global equity assessments.

Conclusions

The study, therefore, reveals the far-reaching impact of the FF21A module in building 21st Century skills and academic performance among Malaysian science students. Together with Dale's Cone of Experience, the Revised Bloom Taxonomy, and the Virtual Learning Environment (VLEs), the module effectively discussed collaborative, technology-mediated learning,

with an emphasis on bridging theoretical understanding with real-world application. In effecting systemic transformation from these findings, policymakers and educators must take a multi-pronged approach. First, the widespread implementation of the FF21A framework to other STEM domains such as mathematics, engineering, and technology can serve to fill Malaysia's dire shortage of qualified professionals, especially in disciplines like engineering with the current engineer-to-population ratio (1:170) far behind the global bench-marking. This is relevant to the Malaysia Education Blueprint 2013-2025, which prioritizes equal access to quality STEM education as a driver for innovation and economic growth. Although fidelity checks confirmed excellent module delivery, differences in VLE access speed between rural and urban areas sometimes affected pacing of activities. Future iterations need to include adaptive offline options for less connected contexts. The teacher training model was effective (3-day workshop + biweekly PLCs) but needs scaling for national interventions.

Secondly, teacher training must place greater emphasis on enhancing teachers' skills in related digital tools and pedagogical content in the application of VLEs. The professional development of such educators should emphasize student-centered facilitation, module customization, and solving technology-related obstructions designed with the involvement of universities and EdTech providers. The importance of teacher preparedness, cited in this study as a fundamental success factor, emphasizes the urgency of that assistance. Access to digital resources must also be equitable across the board to attain a "no-child-left-behind" scenario. Rural schools face unique infrastructure challenges and will need tailored investments in high-speed Internet, devices at subsidized rates, and contextually relevant VLE content. Such public-private partnerships would seek to pool resources to narrow the gap between urban and rural, especially in the particularly underdeveloped states of Sabah and Sarawak while anchored in initiatives such as the National Fourth Industrial Revolution Policy. This would promote productive new generations of learners—agile and conversant with technology—ready to operate in a digital economy worldwide. Policymakers, educationalists, and industrialists must coalesce in the spirit of making such recommendations an actionable reality so that, in effect, its success becomes a central feature in driving education transformation in the country.

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