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An Exploration of Predictors of STEM Knowledge Integration among Generation Z Students: Focusing on 21st Century Skills

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Resumen: This study seeks to predict and examine the factors influencing the degree of Science, Technology, Engineering, and Mathematics (STEM) knowledge integration among Generation Z students. Specifically, it aims to evaluate and compare the relative significance of three primary categories of explanatory variables: (1) variables related to experiential tourism, (2) variables pertaining to learning management models, and (3) variables associated with STEM skills. Adopting a predictive quantitative research design, this study gathered data from a sample of 840 Generation Z students, aged between 18 and 22, enrolled in tourism and hospitality programmes. The sample size was determined using G*Power software and selected through a multi-stage quota random sampling technique. Data were collected via eleven summated rating scale questionnaires, each comprising six response options. The instruments yielded an average reliability coefficient of 0.794. Additionally, problem-solving skills exhibited a strong positive correlation with critical thinking skills ($r = 0.692$), highlighting the pivotal role of analytical competencies in interdisciplinary knowledge integration. These results underscore the critical value of instructional designs that foster active participation and cognitive engagement. The findings affirm a moderately strong positive association between STEM knowledge integration and several key variables, particularly student engagement, experiential learning, and problem-solving skills.

Keywords*:* Exploration, Predictors, STEM Skills, Generation Z, Experiential Tourism, Teaching, Learning.

1. Introduction

The rapid progression of globalisation and digital technologies has led to significant transformations in societal, educational, and economic domains. This trend aligns with the concept of Disruptive Innovation proposed by Markides (2005), which posits that emerging technologies are reshaping traditional educational paradigms. Conventional methods are increasingly inadequate in addressing the evolving needs of learners in the twenty-first century. Generation Z, defined as individuals born between 1995 and 2010, has grown up in a technologically rich environment characterised by pervasive access to digital media and information technologies. Their preferred learning approaches prioritise practical engagement, real-world relevance, and the incorporation of modern technologies. A survey conducted by Nicholas and Arlene (2020) found that 74% of Generation Z students expect their education to be directly connected to practical contexts, while 62% prefer immersive, hands-on experiences to gain authentic understanding.

In this context, STEM competencies have become increasingly critical, particularly in cultivating skills such as critical thinking, innovation, and problem-solving (Van Der Vlies, 2020). STEM education offers frameworks for reasoning, analysis, and innovation development aimed at addressing global challenges such as sustainable energy, healthcare, environmental technologies, and resource management. It also contributes significantly to the achievement of the Sustainable Development Goals (SDGs), while equipping learners with the competencies needed for sustainable societal development. The World Economic Forum (2023) has projected that STEM-related capabilities will be essential for over 85% of job categories by 2030. Despite this urgency, higher education institutions continue to lack learning management approaches tailored to the distinct learning preferences of Generation Z students, particularly those enrolled in tourism and hospitality programmes (World Economic Forum, 2023). This gap is especially evident in efforts to integrate STEM with experiential learning outside the classroom, a strategy that Bell (2010) has affirmed as highly effective for the development of advanced competencies.

In this regard, tourism-related educational experiences can be understood within the framework of Place-Based Education, as outlined by Sobel (2004), which promotes learning through engagement in authentic settings such as community sites, cultural centres, and tourist destinations. This pedagogical model is especially suitable for the development of professional skills within service-oriented disciplines. Real-world learning facilitates the acquisition of essential abilities such as strategic planning, effective communication, and systems-based thinking. Empirical support for this model is offered by Maelia (2023), whose research revealed a 68% increase in learner engagement among students participating in on-site educational activities compared to those in traditional settings.

Although conceptual models exist that link STEM with experiential learning, empirical investigations remain scarce within Thai higher education. There is a lack of studies identifying statistical predictors that elucidate the relationships among STEM skills, experiential learning, and pedagogical approaches such as Problem-Based Learning, Project-Based Learning, and Experiential Learning (EL). The experimental research of Renninger et al. (1992) also highlighted the absence of standardised assessment tools for evaluating out-of-classroom learning outcomes, which are often judged qualitatively due to a lack of quantitative benchmarks. Supporting this observation, Catana and Brilha (2020), in a review of UNESCO's 2020 educational agenda, reported that 60% of developing nations have yet to implement systematic evaluation frameworks for assessing experiential learning beyond classroom environments.

In the Thai context, numerous university instructors continue to face challenges in designing integrated learning activities that are appropriate for the local context. This issue is particularly pronounced in faculties well-positioned to deliver experiential learning, including the Faculty of Tourism and Service Industry, the Faculty of Cultural Environment and Ecotourism, the Faculty of Hospitality and Tourism, and the Faculty of Hotel and Tourism Management. This situation underscores a clear research gap in the integration of STEM and professional competencies. There is a critical need for quantitative investigations to identify statistical indicators, emerging trends, or predictive variables that influence the effectiveness of combining STEM skills with experiential approaches. This is especially pertinent for Generation Z students, who represent a pivotal future workforce in the service sector. These students must develop advanced learning capabilities to thrive in a rapidly changing and highly competitive professional landscape.

2. Literature Review

One of the essential competencies that students must acquire is the ability to integrate STEM knowledge. This skill involves synthesising and applying concepts from STEM in a comprehensive manner to address complex issues and foster innovation in practical contexts. Such an ability is particularly critical in the service and tourism industries, which operate within multifaceted systems and demand a wide array of skills. The concept of cross-disciplinary and experiential learning, as advocated by VanTassel-Baska and Wood (2023) through their Integrated Curriculum and Experiential Learning Theory, supports the notion that knowledge becomes more profound when it is acquired through practical, interdisciplinary experiences. They argue that intellectual development and the real-world application of knowledge are hindered when learning is compartmentalised into isolated, single-discipline subjects. Conversely, an integrated learning approach enhances the ability to draw on varied knowledge sources to devise solutions. Moreover, the Framework for 21st Century Learning underlines the significance of nurturing the four key competencies of Critical Thinking, Creativity, Collaboration, and Communication (the 4Cs), which are regarded as central to developing STEM-related skills for today's workforce (Gilbert, 2016). These competencies are particularly vital in the service and tourism sectors, which are constantly evolving and must respond rapidly to changing demands. For instance, information technology is employed to optimise customer service experiences, while data analytics is used to interpret consumer behaviour and anticipate tourism trends (Xiang, Magnini & Fesenmaier, 2015).

Generation Z, having grown up immersed in digital technologies, is the first cohort to have experienced education primarily through digital platforms. According to the Constructivist perspective, particularly Social Constructivism (Picton, 2023), learners assimilate knowledge more effectively through social interaction and collaborative engagement. Members of Generation Z are inclined towards educational methods that involve hands-on experiences, customisation, and immediate feedback. Therefore, instructional approaches that align with these characteristics—such as Project-Based Learning, Blended Learning, and Experiential Tourism-Based Learning—are highly suitable in modern pedagogical practice. These methods support the integration of

STEM knowledge with authentic problem-solving and innovation. For instance, students may be engaged in projects involving the management and interpretation of geographic and economic data for sustainable tourism, or the development of personalised travel itineraries using IoT technologies and mobile applications. Such activities exemplify the application of STEM competencies necessary in contemporary service professions.

In the context of experiential tourism, Kolb's Experiential Learning Cycle serves as a relevant framework. As outlined by Abdulwahed and Nagy (2009), effective learning proceeds through four sequential stages: Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation. This cycle is particularly applicable to educational scenarios conducted in the field, such as learning experiences at tourism sites, followed by reflective analysis and the design of novel services based on the needs of visitors. These practices are particularly beneficial where staff must combine creative insight with analytical skill (Manzoni et al., 2020). Strengthening Generation Z students' ability to integrate STEM knowledge effectively necessitates not only an appreciation of the learners themselves but also the strategic combination of educational theories and contemporary learning paradigms in developing instructional models that connect academic content with real-life applications. This is especially important within the service and tourism domains, which demand adaptable and well-rounded individuals capable of addressing emerging challenges.

STEM Skills encompass the integration of knowledge across Science, Technology, Engineering, and Mathematics, which are particularly relevant for Generation Z students. In an era characterised by rapid technological advancement and innovation, these competencies are crucial for sustaining the momentum of global economic and societal progress. Preparing Generation Z for participation in the future labour force necessitates the development of core skills essential for functioning effectively in the 21st century. This subject is widely addressed within both academic literature and policy discussions. Four fundamental competencies are particularly emphasised: critical thinking, problem-solving, technological proficiency, and collaborative ability. Numerous studies have indicated that these factors directly influence the successful integration of STEM knowledge and skills (Bybee, 2013; National Research Council, 2012; Thibaut et al., 2018). Cultivating these competencies not only equips students for future career demands but also enhances their adaptability and promotes continuous learning in a dynamic global context. Based on an analysis of existing literature and theoretical models, the researchers have identified four essential STEM-related skills for Generation Z learners:

Logical thinking is a foundational element in comprehending scientific and mathematical concepts and represents a vital component within both scientific and technological disciplines. This skill involves the ability to critically assess information, synthesise understanding, validate data sources, and systematically plan experimental or investigative procedures (Zohar & Dori, 2003). Given their upbringing in a digital environment abundant with information, Generation Z students must develop the ability to discern credible data, evaluate its reliability, and critically interpret it with thoughtful reasoning. These capabilities will support informed decision-making and the creation of new knowledge (Vogel, 2023). Whereas problem-solving constitutes a central aspect of STEM knowledge integration, as students must be able to identify and implement innovative strategies to resolve real-world challenges (Jonassen, 2010). Instructional activities that prioritise design thinking and context-based learning enhance students' capabilities by enabling them to identify problems, analyse underlying causes, explore multiple solutions, assess alternatives, and apply interdisciplinary knowledge to create original and effective responses (Richard et al., 2013).

Generation Z students, having grown up in a highly digitalised environment, are generally proficient in using various technological tools and platforms (Prensky, 2008). However, successful integration of STEM skills demands more than basic familiarity; it requires the creative and analytical application of technology for learning, problem-solving, and innovation. This might include using simulation tools, programming to operate devices, analysing large datasets, or applying digital fabrication techniques. Zhai et al. (2021) demonstrated that guiding students to use technology as a design and innovation tool significantly enhances their STEM integration. Additionally, digital literacy—including the ability to access, evaluate, and ethically use digital information—is crucial for Generation Z to derive maximum benefit from technological adoption (Gui & Argentin, 2011).

Teamwork skills, although Generation Z is often adept at self-directed learning and digital interaction, remain indispensable for effective STEM integration. Modern challenges are multifaceted and necessitate diverse perspectives for their resolution (Salas, Cooke & Rosen, 2008). Participation in interdisciplinary projects or innovation-focused competitions frequently relies on collaborative competence. Students must be able to communicate clearly, contribute ideas, appreciate alternative viewpoints, and engage in collective decision-making to reach shared goals. According to Johnson and Johnson (2015), cooperative learning not only enhances academic achievement but also cultivates essential social competencies, such as active listening, interpersonal communication, negotiation, and critical thinking, through collaborative discourse.

Instead of these skills, eexperiential Tourism prioritizes direct engagement in real-world activities or practical training environments, with the objective of fostering deeper comprehension and tangible skill development among learners (Beard & Wilson, 2018). For Generation Z students, such approaches facilitate the connection between theoretical understanding and practical contexts, thereby supporting the cultivation of essential competencies for the 21st century (Roberts, 2012). Within the realm of STEM education, experiential learning plays a pivotal role in translating abstract concepts into concrete knowledge through active participation. Based on a thorough review of pertinent theories and scholarly literature, three interrelated variables have been identified:

Learner Engagement is recognised as a critical determinant of successful STEM education outcomes (Fredricks, Blumenfeld & Paris, 2004). Engagement can be categorised into behavioural, emotional, and cognitive domains (Sharan & Tan, 2008). Curriculum-related sociocultural elements—such as clearly defined objectives, relevance of content, and instructional support—significantly influence learners' perceived control and the value attributed to learning, ultimately affecting their level of participation (Ainley & Ainley, 2011; Wentzel & Miele, 2009). The presence of supportive educators and a sense of community affiliation positively correlates with increased STEM engagement (Pekrun & Linnenbrink-Garcia, 2012). Moreover, technologies such as Virtual Reality (VR) and Augmented Reality (AR) have been shown to boost student engagement, especially when aligned with learners' interests and authentic real-life scenarios (Merchant et al., 2014).

Activity Intensity pertains to the cognitive demands and complexity associated with a given task. Activities with higher intensity require learners to exercise greater intellectual effort and advanced skill sets (Sailer & Sailer, 2020). Such activities are instrumental in promoting critical thinking, complex problem-solving, and the practical application of interdisciplinary knowledge. Challenging tasks are essential for effective learning, as appropriate difficulty levels are linked to deeper understanding and sustained engagement (Soderstrom & Bjork, 2015). In the context of STEM, gamified environments and serious games can significantly enhance motivation and learning outcomes (Knifsend, 2018). High-intensity activities that incorporate interactive elements and intellectual challenges are particularly effective for capturing the interest of Generation Z students (Cilliers et al., 2018). It is the responsibility of instructors to ensure adequate scaffolding is provided to support learners during such tasks (Sailer & Sailer, 2020).

Perceived Value, or the degree to which students recognise the usefulness and relevance of a learning experience, significantly affects their motivation and satisfaction (Eccles, O'Neill & Wigfield, 2005). This concept encompasses utility value, attainment value, and intrinsic value (Beymer, Ferland & Flake, 2021). Learners who engage in practical experiences, such as internships, often perceive their education as more valuable and are generally better prepared for future employment (Gault, Redington & Schlager, 2000). These experiences bridge the gap between theory and application. Immersive learning environments allow students to appreciate the real-world relevance of academic content, thereby reinforcing the perceived applicability and significance of their studies.

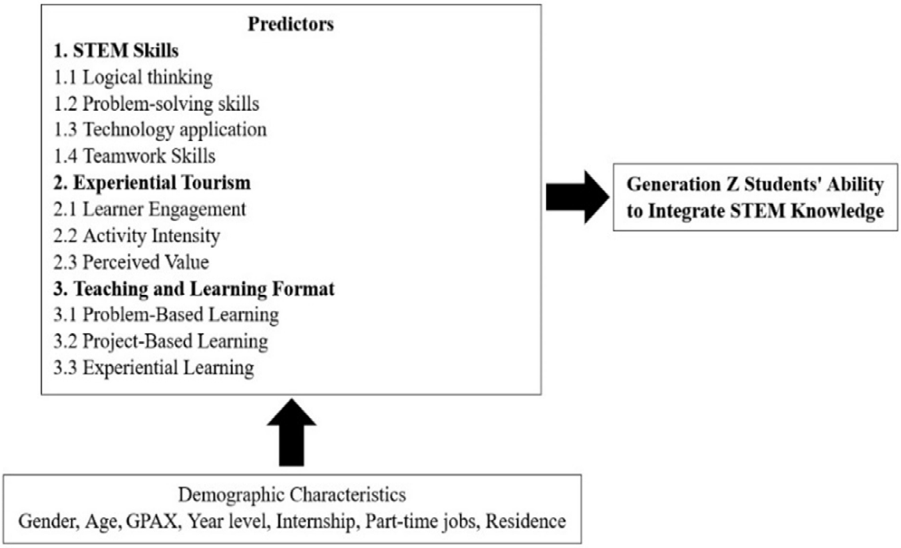
Teaching and learning formats significantly influence the efficacy of education, particularly in preparing students to meet contemporary challenges. Learner-centred methodologies that cultivate critical 21st-century skills are essential in modern educational environments. This study highlights three prominent instructional models commonly employed in undergraduate programmes—Problem-Based Learning, Project-Based Learning, and Experiential Learning—each contributing uniquely to the integration of STEM knowledge with practical competencies:

Problem-Based Learning (PBL) employs authentic, real-life problems as the foundation for instructional activities (Seibert, 2021). The primary aim is to nurture critical thinking and teamwork capabilities. For Generation Z, who have grown up immersed in digital technologies and extensive information sources, PBL serves as an effective means of enhancing their ability to systematically analyse problems and devise strategic solutions. Empirical findings by Seibert confirm that this instructional approach significantly bolsters the critical and analytical skills of Gen Z learners.

Project-Based Learning (PjBL) is centred around executing projects that mirror real-world contexts, encouraging the integration of multidisciplinary knowledge (Sviatko, 2024). This model aligns well with Generation Z students, who are familiar with digital collaboration tools and value teamwork. PjBL facilitates the development of cooperative skills and the application of knowledge in practical situations. According to Sviatko (2024), engagement in project-based tasks enhances students' capacity for self-regulation and collaborative problem-solving, making it a valuable method for fostering essential workplace competencies.

Experiential Learning (EL) is grounded in the principle that profound and sustainable learning is achieved through direct engagement in practical tasks. This approach enables students to relate theoretical knowledge to tangible experiences, promoting both personal and professional growth (Kolb, 2014). EL is particularly relevant in STEM education as it allows learners to actively engage in experimentation, reflection, and iterative improvement, thereby acquiring skills that are critical in a rapidly evolving global economy as shown in Figure 1 Conceptual Framework.

Figure 1: Conceptual Framework.



3. Hypotheses

H1: The three main groups of variables; STEM skills, experiential tourism, and teaching and learning formats, positively influence STEM knowledge integration with statistical significance.

H2: The group of variables on experiential tourism can predict STEM knowledge integration in Generation Z students with statistical significance.

H3: The group of variables on teaching and learning formats can predict STEM knowledge integration in Generation Z students with statistical significance.

H4: The group of variables on STEM skills can predict STEM knowledge integration in Generation Z students with statistical significance.

H5: The multiple regression analysis model shows a sequential ordering of variable groups on experiential tourism, followed by teaching and learning formats, and STEM skills. The total regression coefficient for each group shows a statistically significant increase.

H6: The group of variables on STEM skills, the group of variables on experiential tourism, and the group of variables on teaching and learning formats can jointly predict STEM knowledge integration in Generation Z students with statistical significance and can also predict no less than 40% of the variance, considering both the overall group and subgroups.

4. Methodology

4.1. Research Design and Ethical Considerations

This study adopts a quantitative predictive research design, aimed at forecasting and examining the variables that affect the integration of STEM knowledge among Generation Z students. Multiple regression analysis was utilised as outlined by Stolzenberg (2004), to assess and compare the relative impact of three principal variable groups: experiential tourism, teaching and learning formats, and STEM-related skills. The results of this analysis provide valuable insights for the advancement of instructional strategies and the enhancement of students' STEM capabilities. Furthermore, the outcomes may inform policy formulation and curricular development. The findings are also applicable to the creation of innovative educational models that align with student behaviour and contextual conditions in a sustainable and responsive manner. This research project received formal approval from the Research Ethics Committee under the reference number A04048/2023. Ethical principles were rigorously observed throughout all phases of the study. The researchers implemented comprehensive safeguards to ensure the protection of participants' rights, well-being, and dignity. Prior to participation, all individuals provided informed consent voluntarily, without exposure to coercion, undue pressure, or inappropriate inducements. Participant confidentiality and personal data were strictly protected through rigorous anonymity protocols. No unauthorised personnel had access to identifiable information, and all data collected were exclusively employed for academic purposes, ensuring that no harm could result from its use or disclosure.

4.2. Sample

The participants in this study comprised Generation Z students, aged between 18 and 22 years, who were enrolled in tourism and hospitality faculties throughout Thailand. The sample size was calculated using G*Power software, employing a 95% confidence level and a maximum margin of error of 5% (Faul et al., 2009; Kang, 2021). The analysis indicated that a minimum of 800 respondents would be appropriate. To accommodate the possibility of incomplete responses, the researchers expanded the sample size by an additional 5–10%, resulting in a final target sample of approximately 840 students. A multi-stage quota random sampling technique was employed to ensure representativeness and national coverage of the target population (Hossan, Dato' Mansor & Jaharuddin, 2023). The sampling process was executed in two stages. In the first stage, universities were randomly selected from six distinct regions across Thailand: Northern, Northeastern, Western, Central, Eastern, and Southern. Each region contributed approximately 140 students, sourced from four universities, totalling 24 institutions. This structure facilitated the collection of data that accurately reflected the educational contexts of tourism and hospitality students across the country. In the second stage, student participants were selected based on their academic year, grouped into two categories: first and second-year students, and third and fourth-year students.

Eligibility criteria required that participants be enrolled in tourism and hospitality programmes and have been exposed to STEM-integrated instructional approaches. Specifically, participants were expected to have engaged in educational experiences incorporating experiential tourism, or have undertaken modules based on Problem-Based Learning, Project-Based Learning, or Experiential Learning frameworks. A researcher-developed self-assessment questionnaire was used as a screening tool to verify participants' alignment with these criteria. This ensured that only individuals with direct and relevant learning experiences participated, thereby enhancing the study's validity. Data collection was facilitated through four distinct questionnaire sets (A, B, C, and D), each aligned with variables outlined in the research framework. To reduce potential response biases and errors associated with repetitive answering patterns, the question order within each set was systematically rotated. This procedural control helped mitigate order effects and respondent fatigue, thereby enhancing the reliability and validity of the collected data. From the total sample of 840 participants, 404 were male (48.10%) and 436 were female (51.90%). The mean age of the respondents was 20 years and 7 months, with a standard deviation of 0.60. The average grade point average (GPA) reported was 3.26 (Table 1).

Table 1: Socio-Demographic Background of the Sample.

Characteristic	Category	Frequency (%)
Sample Group	Generation Z students (aged 18-22) currently studying in faculties of tourism and hospitality	840 (100.00%)
Questionnaire Set	Set A	210 (25.00%)
	Set B	210 (25.00%)
	Set C	210 (25.00%)
	Set D	210 (25.00%)
Gender	Male	404 (48.10%)
	Female	436 (51.90%)
Grade Point Average Index (GPAX)	Mean: 3.26 (SD = 0.52)	
Average Age	20 years 7 months (SD = 0.60)	
Year Level	1st Year	195 (23.21%)
	2nd Year	210 (25.00%)
	3rd Year	229 (27.26%)
	4th Year	206 (24.52%)
STEM Skills Understanding Levels	Understand	454 (54.05%)
	Partially Understand	327 (38.93%)
	Not Understand	59 (7.02%)
Cooperative Education Experience	Never Interned	413 (49.17%)
	Interned	427 (50.83%)
Working While Studying	Not Working While Studying	498 (59.29%)
	Working While Studying	342 (40.71%)
Accommodation	Living with Parents	207 (24.64%)
	Living with Relatives	126 (15.00%)
	Living with Friends	241 (28.69%)
	Living Alone in Dormitory	266 (31.67%)
Note: Missing Values are Excluded.		

4.3. Instruments

The research employed 11 newly constructed instruments based on the Summated Rating Scale format. These instruments were developed by the researchers through the synthesis of relevant concepts, theoretical frameworks, and prior empirical studies. Each instrument consisted of a series of statements to which participants indicated their level of agreement using a 6-point Likert-type scale, ranging from “Most true” to “Not true at all” (Desselle, 2005). To ensure content appropriateness, the instruments underwent expert validation by five specialists in the fields of tourism, educational management, and behavioural sciences. The experts evaluated the extent to which each item aligned with the objectives, content domains, conceptual frameworks, and measurement purposes of the study. This validation process resulted in an Index of Item-Objective Congruence (IOC) ranging from 0.80 to 1.00, indicating a high degree of item alignment (Turner & Carlson, 2003).

Following revisions based on the experts' feedback, the revised instruments were pilot-tested with a group of 120 participants who exhibited similar demographic and academic characteristics to the primary sample. The quality of the questionnaire items was evaluated using Findley (1956) Item Discrimination technique, as well as Item-Total Correlation analyses (excluding each item from its total score) in accordance with Hajjar (2018). To evaluate Construct Validity, Confirmatory Factor Analysis was performed following the framework proposed by Harrington (2009). The minimum standard for Construct Validity acceptance required items to satisfy at least three out of five relevant criteria. All 11 instruments exceeded this threshold by fulfilling all five criteria, thereby confirming strong Construct Validity. In addition to validity, the internal consistency of the instruments was assessed using Cronbach's Alpha Coefficient. The reliability coefficients ranged from 0.76 to 0.83, reflecting acceptable to good reliability across the instruments (Kılıç, 2016) (Table 2).

Table 2: Quality of Questionnaires in the Research.

Questionnaires	**No**	**α**	**Confirmatory Factor Analysis**						
			χ^2	**df**	**P-Value (>0.05)**	**RMSEA (≤0.06)**	**CFI (≥0.95)**	**TLI (≥0.95)**	**SRMR (≤0.08)**
STEM Knowledge Integration Ability	14	0.83	97.47	91	0.08	0.05	0.98	0.97	0.06
Logical Thinking	13	0.79	90.68	82	0.07	0.03	0.97	0.96	0.05
Problem-Solving Skills	14	0.78	96.36	79	0.08	0.05	0.98	0.97	0.06
Technology Application	10	0.76	82.76	70	0.06	0.04	0.97	0.97	0.04
Teamwork Skills	12	0.79	78.93	77	0.07	0.04	0.97	0.96	0.05
Learner Engagement	14	0.80	92.20	81	0.08	0.05	0.98	0.97	0.06
Activity Intensity	12	0.79	81.46	76	0.06	0.03	0.97	0.97	0.04
Perceived Value	12	0.80	83.35	74	0.07	0.03	0.97	0.96	0.04
Problem-Based Learning	14	0.81	93.42	79	0.08	0.05	0.98	0.97	0.06
Project-Based Learning	10	0.79	71.86	72	0.06	0.05	0.96	0.95	0.06
Experiential Learning	14	0.80	87.20	83	0.07	0.04	0.98	0.97	0.05

Note: *Confirmatory factor analysis used a passing criterion of 3 out of 5 criteria or more, especially when the χ2 value was not statistically significant. **This research gives more importance to the t value than the r value, with the selection criteria being t ≥ 2.00 and r ≥ 0.20. ***The t and r values are presented in Appendix A of the full research report.

4.4. Data Analysis

This study employed inferential statistical techniques to test six hypotheses and to assess the significance of relationships between the independent and dependent variables. The analytical methods applied were as follows:

1. The Pearson Product-Moment Correlation Coefficient was utilised to determine the strength and direction of the linear association between pairs of independent variables. This statistical measure provided insight into the extent to which changes in one variable corresponded with changes in another (Puth, Neuhäuser & Ruxton, 2014).
2. Multiple Regression Analysis was applied to explore the extent to which multiple independent variables could collectively predict the outcome of the dependent variable. This method facilitated the identification of statistically significant predictors, and it assessed each variable's contribution to the explanatory power of the overall model (Petrocelli, 2003; Stolzenberg, 2004).

5. Results

The descriptive analysis of means and standard deviations for all eleven research variables, as shown in Table 3, grouped the data into three primary categories: (1) STEM Skills, (2) Experiential Tourism, and (3) Teaching and Learning Formats. Among these, Problem-Based Learning recorded the highest mean score (M = 48.76, SD = 8.48), followed by Project-Based Learning (M = 47.39, SD = 8.95) and Problem-Solving Skills (M = 45.74, SD = 6.58). These findings indicate that the participants generally possessed a strong background in learning approaches that emphasise cognitive processes and hands-on application. Conversely, the lowest mean score was observed for Teamwork Skills (M = 40.98, SD = 9.72), suggesting a potential need to strengthen collaborative learning activities that foster interpersonal communication and group interaction. Most standard deviation values ranged between 6 and 10, signifying a moderate level of dispersion, which implies variation in students' experiences and skill levels. Variables with relatively high variability, such as Perceived Value and Activity Intensity, further illustrate individual differences in perception, likely influenced by contextual factors or the nature of the instructional approaches received. In sum, the descriptive data provide useful insights into designing pedagogical strategies tailored to Generation Z learners. The findings highlight the beneficial role of Active Learning methods in enhancing a diverse set of competencies, especially those integral to effective STEM knowledge integration.

Table 3: Mean, Standard Deviation, and Correlation Coefficients of Variables in the Combined Group (N=840).

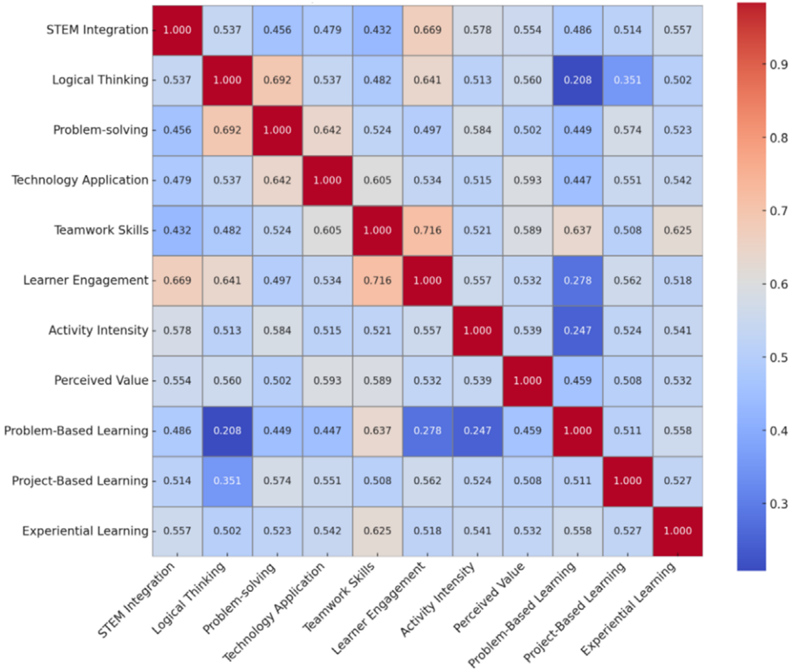
Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1	43.52	6.48	1										
2	45.46	7.79	.537**	1									
3	45.74	6.58	.456**	.692**	1								
4	42.89	8.45	.479**	.537**	.642**	1							
5	40.98	9.72	.432**	.482**	.524**	.605**	1						
6	44.85	7.81	.669**	.641**	.497**	.534**	.716**	1					
7	41.54	8.37	.578**	.513**	.584**	.515**	.521**	.557**	1				
8	43.45	9.56	.554**	.560**	.502**	.593**	.589**	.532**	.539**	1			
9	48.76	8.48	.486**	.208**	.449**	.447**	.637**	.278**	.247**	.459**	1		
10	47.39	8.95	.514**	.351**	.574**	.551**	.508**	.562**	.524**	.508**	.511**	1	
11	45.70	7.14	.557**	.502**	.523**	.542**	.625**	.518**	.541**	.532**	.558**	.527**	1

Note: N = 840. *p<.05, **p<.01
Variables Codes: 1: STEM knowledge Integration Ability, 2: Logical Thinking, 3: Problem-Solving Skills, 4: Technology Application, 5: Teamwork Skills, 6: Learner Engagement, 7: Activity Intensity, 8: Perceived Value, 9: Problem-Based Learning, 10: Project-Based Learning, 11: Experiential Learning

The findings from the Pearson's Correlation Coefficient analysis across the eleven variables (Figure 2) confirmed Hypothesis 1. All variable pairs exhibited statistically significant positive correlations at the 0.01 level (p < .01). Based on the interpretation criteria of correlation strength proposed by Cohen (2008) and Hair Jr et al. (2010), the coefficients were categorised into three levels. The variable demonstrating the most substantial relationships was the ability to integrate STEM knowledge, which showed moderate correlations with several factors: student engagement (r = 0.669), activity intensity (r = 0.578), experiential learning (r = 0.557), perceived value of experience (r = 0.554), project-based learning (r = 0.514), and problem-solving skills (r = 0.456). These findings imply that engaging students in diverse and intensive learning activities is positively associated with enhancing their capacity to integrate STEM knowledge.

Among the observed relationships, problem-solving skills had the strongest correlation with logical thinking ability (r = 0.692), followed by student engagement (r = 0.641). These results indicate that both analytical skills and active participation in learning activities have a direct impact on logical reasoning, which is a critical aspect of scientific cognition. Additionally, teamwork skills demonstrated a high correlation with student engagement (r = 0.716), aligning with Johnson and Johnson (2015) proposition that collaborative learning fosters greater engagement and improved academic outcomes. Problem-Based Learning also exhibited moderate correlations with experiential learning (r = 0.558) and STEM knowledge integration ability (r = 0.486). These results suggest that this instructional model effectively cultivates analytical thinking and facilitates multidimensional knowledge integration. Its efficacy is particularly evident when students can apply real-world experiences as foundational elements in the problem-solving process.

Figure 2: Heatmap Showing Correlations Matrix Among STEM Skills, Experiential Tourism, Teaching and Learning Format (N = 840).



	STEM Integration	Logical Thinking	Problem-solving	Technology Application	Teamwork Skills	Learner Engagement	Activity Intensity	Perceived Value	Problem-Based Learning	Project-Based Learning	Experiential Learning
STEM Integration	1.000	0.537	0.456	0.479	0.432	0.669	0.578	0.554	0.486	0.514	0.557
Logical Thinking	0.537	1.000	0.692	0.537	0.482	0.641	0.513	0.560	0.208	0.351	0.502
Problem-solving	0.456	0.692	1.000	0.642	0.524	0.497	0.584	0.502	0.449	0.574	0.523
Technology Application	0.479	0.537	0.642	1.000	0.605	0.534	0.515	0.593	0.447	0.551	0.542
Teamwork Skills	0.432	0.482	0.524	0.605	1.000	0.716	0.521	0.589	0.637	0.508	0.625
Learner Engagement	0.669	0.641	0.497	0.534	0.716	1.000	0.557	0.532	0.278	0.562	0.518
Activity Intensity	0.578	0.513	0.584	0.515	0.521	0.557	1.000	0.539	0.247	0.524	0.541
Perceived Value	0.554	0.560	0.502	0.593	0.589	0.532	0.539	1.000	0.459	0.508	0.532
Problem-Based Learning	0.486	0.208	0.449	0.447	0.637	0.278	0.247	0.459	1.000	0.511	0.558
Project-Based Learning	0.514	0.351	0.574	0.551	0.508	0.562	0.524	0.508	0.511	1.000	0.527
Experiential Learning	0.557	0.502	0.523	0.542	0.625	0.518	0.541	0.532	0.558	0.527	1.000

The outcomes of the Multiple Regression Analysis examining the impact of different variable groups on the prediction of STEM knowledge integration ability among Generation Z students are summarised in Table 4. The findings indicate that variables from all three groups—experiential tourism, teaching and learning formats, and STEM skills—significantly contributed to the prediction of students' ability to integrate STEM knowledge. The analysis is detailed in the following three models:

1. Model 1 comprised the experiential tourism variables, namely Learner Engagement (Variable 5), Activity Intensity (Variable 6), and Perceived Value (Variable 7). These predictors were found to significantly influence the STEM knowledge integration ability, thereby confirming Hypothesis 2 ($F = 29.922$, $p < .001$). The model reported a coefficient of determination (R^2) of 0.113, with an adjusted R^2 of 0.109. Learner Engagement emerged as the most influential variable ($\beta = 0.330$, $t = 5.190$, $p < .001$), followed by Perceived Value ($\beta = 0.291$) and Activity Intensity ($\beta = 0.223$). Although this model yielded the lowest R^2 value among the three, the substantial impact of Learner Engagement highlights the significance of meaningful learning experiences in fostering interdisciplinary knowledge integration.
2. Model 2 involved variables related to teaching and learning formats, specifically Experiential Learning (Variable 10), Problem-Based Learning (Variable 8), and Project-Based Learning (Variable 9). This model demonstrated a higher predictive capacity ($R^2 = 0.338$, Adjusted $R^2 = 0.332$, $\Delta R^2 = 0.225$), thereby supporting Hypothesis 3. Among these, Experiential Learning was the most impactful predictor ($\beta = 0.352$, $t = 5.821$, $p < .001$), indicating that students engaged in hands-on, practical learning activities exhibited a greater propensity to integrate STEM knowledge effectively, in comparison with those participating in other instructional formats.
3. Model 3 focused on STEM skills variables, including Problem-Solving Skills (Variable 2), Technology Application (Variable 3), Logical Thinking (Variable 1), and Teamwork Skills (Variable 4). This model accounted for 35.70% of the variance in STEM knowledge integration ability, thereby supporting Hypothesis 4 ($R^2 = 0.357$, Adjusted $R^2 = 0.350$, $\Delta R^2 = 0.019$). Although the incremental R^2 was modest, all variables reached statistical significance ($p < .001$). Notably, Problem-Solving Skills had the highest standardised coefficient ($\beta = 0.374$, $t = 5.704$), highlighting the central role of problem-solving in STEM knowledge integration. This finding underscores the necessity of interdisciplinary knowledge to effectively analyse, synthesise, and resolve real-world challenges.

Furthermore, a Hierarchical Multiple Regression Analysis was conducted to evaluate the logical sequence of variable groups from external to internal influences. The sequence began with contextual factors (experiential tourism variables, Model 1), followed by instructional strategies (teaching and learning formats, Model 2), and concluded with intrinsic learner factors (STEM skills, Model 3). The results demonstrated a significant increase in the coefficient of determination (R^2) at each stage, thereby supporting Hypothesis 5.

To ensure the appropriateness of the multiple regression model and verify the reliability of the estimated regression coefficients, the researchers assessed potential multicollinearity among the independent variables by examining both the Tolerance and Variance Inflation Factor (VIF) values, as outlined in Table 4. In accordance with the criteria suggested by Hair Jr et al. (2010), multicollinearity is considered problematic if a variable exhibits a Tolerance value below 0.10 or a VIF exceeding 5. The analysis revealed that all independent variables across the three models displayed Tolerance values between 0.753 and 0.990, and VIF values ranging from 1.153 to 1.837. These figures fall within acceptable limits, indicating no signs of multicollinearity. Specifically, the VIF values remained well below the critical threshold of 5, with values under 2 considered safe for model interpretation, as noted by O'Brien (2007). Based on these findings, it can be concluded that the multiple regression models do not suffer from multicollinearity, and the resulting Standardised Coefficients (Beta) are therefore suitable for accurately interpreting the distinct influence of each independent variable on the STEM knowledge integration ability of Generation Z students.

Table 4: Results of Hierarchical Multiple Regression Analysis of Experiential Tourism, Teaching and Learning Formats, STEM Skills as Predictors of Generation Z Students' Ability to Integrate STEM Knowledge.

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2	ΔR^2	Adj R^2	F	Sig.	Collinearity Statistics	
		B	SE	Beta								Tolerance	VIF
1: Group of Experiential Tourism Variables Predicts the STEM Knowledge Integration Variables	(Constant)	30.950	2.412	-	8.827	.000	0.113	-	0.109	29.922	.000	-	-
	5	0.310	0.037	0.330	5.190	.000						0.990	1.210
	7	0.264	0.028	0.291	3.452	.000						0.869	1.153
	6	0.253	0.025	0.223	2.273	.000						0.864	1.157
2: Group of Teaching and Learning Format Variables Predicts the STEM Knowledge Integration Variables	(Constant)	18.755	2.247	-	8.345	.000	0.338	0.225	0.332	28.419	.000	-	-
	10	0.303	0.034	0.352	5.821	.000						0.851	1.331
	8	0.265	0.031	0.284	4.429	.000						0.814	1.229
	9	0.258	0.027	0.261	2.430	.000						0.807	1.210
3: Group of STEM Skills Variables Predicts the STEM Knowledge Integration Variables	(Constant)	18.615	2.252	-	9.067	.000	0.357	0.019	0.350	35.927	.000	-	-
	2	0.324	0.035	0.374	5.704	.000						0.925	1.837
	4	0.319	0.034	0.337	4.213	.000						0.887	1.575
	1	0.294	0.030	0.299	3.152	.000						0.832	1.264
	3	0.232	0.029	0.258	2.351	.000						0.753	1.256

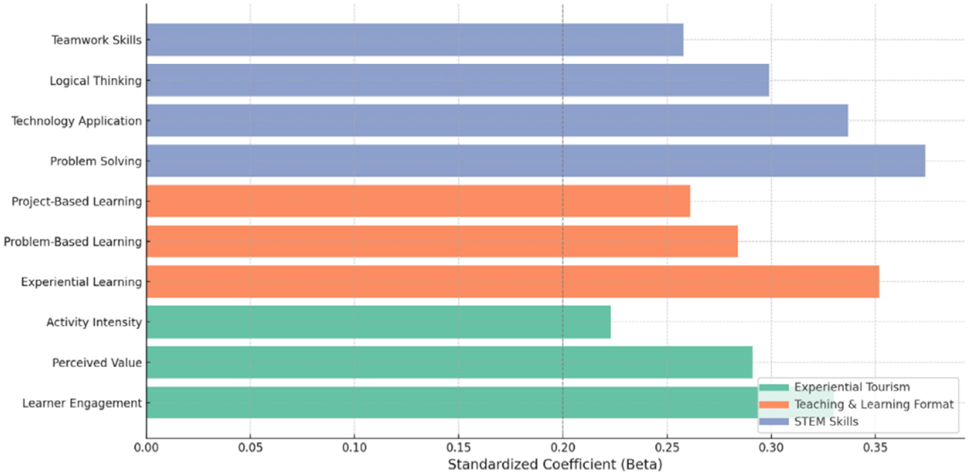
Note: N = 840
Predictors Code : 1: Logical Thinking, 2: Problem-Solving Skills, 3: Technology Application, 4: Teamwork Skills, 5: Learner Engagement, 6: Activity Intensity, 7: Perceived Value, 8: Problem-Based Learning, 9: Project-Based Learning, 10: Experiential Learning

The Standardised Beta Coefficients derived from the Hierarchical Multiple Regression Analysis are illustrated in Figure 3, which demonstrates the varying degrees of influence exerted by variables from all three groups—Experiential Tourism, Teaching and Learning Formats, and STEM Skills—on the STEM knowledge integration ability of Generation Z students. The variable with the strongest influence was Problem-Solving Skills (Beta = 0.374), followed by Experiential Learning (Beta = 0.352) and Technology Application (Beta = 0.337). These results highlight the pivotal role of engaging in practical problem-solving and applying technological tools in enhancing students' ability to integrate STEM knowledge effectively.

Other variables showing a moderate degree of influence included Problem-Based Learning (Beta = 0.284), Project-Based Learning (Beta = 0.261), and Learner Engagement (Beta = 0.330). These findings are consistent with Kolb's (2014) experiential learning theory, which emphasises the importance of learning through direct experience, as well as Bell (2010) assertion regarding the centrality of problem-solving in STEM education. Collectively, the group of STEM Skills—particularly problem-solving and the application of technology—was found to exert a greater impact on STEM knowledge integration than the other two groups. Meanwhile, instructional approaches and experiential learning serve as key structural supports that facilitate the process of STEM integration.

Based on the above, it may be concluded that the development of instructional activities centred on hands-on experience, critical problem-solving, and the creative use of technology is an effective strategy for strengthening Generation Z students' capacity to integrate STEM knowledge. This educational approach aligns well with the demands of 21st-century employment and skill development.

Figure 3: Standardized Coefficients (Beta) of Predictors Affecting Generation Z Students' STEM Knowledge Integration Ability.



A Multiple Regression Analysis was undertaken to identify the predictors of STEM knowledge integration among Generation Z students, as detailed in Table 5. The overall model accounted for 48.10% of the variance, a level regarded as moderate to high according to the criteria proposed by Cohen (2008). The statistically significant predictors ($p < .05$), in descending order of influence, were Learner Engagement (β = 0.41), Perceived Value (β = 0.40), Experiential Learning (β = 0.32), Problem-Solving Skills (β = 0.31), Logical Thinking (β = 0.27), and Teamwork Skills (β = 0.26). SWhen analysed across different subgroups, it was observed that students with a high-Grade Point Average (GPAX > 3.00) exhibited the greatest predictive strength, with the model explaining 46.40% of the variance in STEM knowledge integration. The most influential variables within this subgroup included Learner Engagement (β = 0.44), Perceived Value (β = 0.33), Experiential Learning (β = 0.31), Activity Intensity (β = 0.20), and Teamwork Skills (β = 0.18). Conversely, the subgroup comprising students without any internship experience demonstrated the lowest level of predictive accuracy, with the model accounting for only 32.40% of the variance, which is considered relatively low. In this subgroup, only three predictors reached statistical significance: Problem-Solving Skills (β = 0.29), Experiential Learning (β = 0.25), and Technology Application (β = 0.11). Among the 14 subgroups examined, only eight yielded a predictive power exceeding 40%, providing partial support for Hypothesis 6.

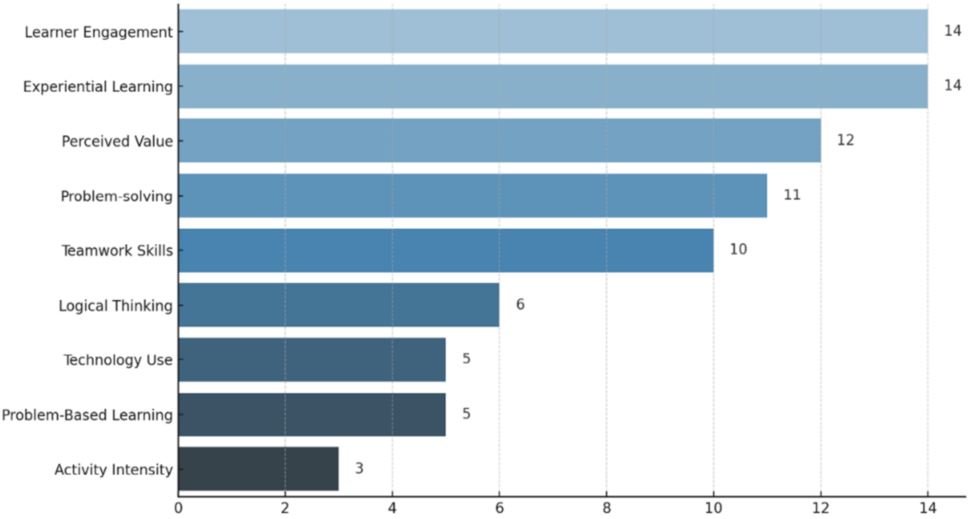
The comprehensive analysis across the entire sample revealed variations in the frequency with which certain variables emerged as statistically significant predictors ($p < .05$), as depicted in Figure 4. Among these, learner engagement and experiential learning were identified most frequently (14 occurrences each), emphasising their pivotal role in educational practices that prioritise active student involvement and direct, real-life learning opportunities. These findings are consistent with the theoretical foundations of Experiential Learning Theory (Abdulwahed & Nagy, 2009) and Student Engagement Theory (Reeve, 2012), which advocate for learner-centred approaches as essential to knowledge acquisition and integration.

Table 5: Results of Multiple Regression Analysis to Predict STEM Knowledge Integration in Generation Z Students, Categorized by Various Demographic Characteristics.

Groups	Case	Prediction	Significant Predictors Code	Beta
Total	840	48.10%	5, 7, 10, 2, 1, 4	0.41, 0.40, 0.32, 0.31, 0.27, 0.26
Male	404	40.50%	5, 7, 10, 2, 4	0.40, 0.37, 0.27, 0.12, 0.11
Female	436	43.60%	5, 7, 2 10, 1	0.41, 0.32, 0.24, 0.13, 0.08
Low GPAX (≤3.00)	364	39.30%	2, 5, 10, 4	0.33, 0.29, 0.12, 0.05
High GPAX (>3.00)	476	46.40%	5, 7, 10, 6, 4	0.44, 0.33, 0.31, 0.20, 0.18
1st Year – 2nd Year	405	39.30%	5, 10, 7, 2, 3	0.47, 0.37, 0.23, 0.19, 0.07
3rd Year – 4th Year	435	45.40%	5, 7, 10, 4, 2, 1	0.46, 0.42, 0.41, 0.40, 0.39, 0.31
Never Interned	413	32.40%	2, 10, 3	0.29, 0.25, 0.11
Interned	427	44.50%	5, 7, 10, 2, 8, 4	0.48, 0.47, 0.43, 0.42, 0.32, 0.28
Not Working While Studying	498	30.50%	5, 4, 10, 8, 3	0.39, 0.36, 0.35, 0.29, 0.27
Working While Studying	342	39.80%	5, 1, 4, 8, 7, 2	0.41, 0.38, 0.33, 0.32, 0.28, 0.06
Living with Parents	207	42.20%	10, 5, 7, 6, 1	0.34, 0.35, 0.29, 0.25, 0.21
Living with Relatives	126	39.40%	10, 5, 7, 2, 6	0.33, 0.31, 0.27, 0.26, 0.20
Living with Friends	241	44.70%	5, 4, 10, 7, 8, 1, 3	0.42, 0.41, 0.37, 0.35, 0.32, 0.29, 0.27
Living Alone in Dormitory	266	45.80%	5, 10, 8, 2, 4, 7, 3	0.45, 0.43, 0.39, 0.36, 0.35, 0.31, 0.18

Note: All beta values were statistical significance at 0.05.
Predictors Code: 1: Logical Thinking, 2: Problem-Solving Skills, 3: Technology Application, 4: Teamwork Skills, 5: Learner Engagement, 6: Activity Intensity, 7: Perceived Value, 8: Problem-Based Learning, 9: Project-Based Learning, 10: Experiential Learning

Figure 4: Frequency of Predictors from Multiple Regression Analysis on STEM Integration.



Perceived value was identified as a significant predictor on 12 occasions, suggesting that students are more likely to engage in meaningful STEM knowledge integration when learning activities are seen as relevant, purposeful, and aligned with real-world or career-related applications. In terms of specific skill sets, problem-solving abilities consistently appeared as a key factor in promoting integrated learning, particularly through the application of interdisciplinary knowledge to resolve complex issues. Teamwork skills also emerged as an important element, reflecting the importance of collaborative engagement in project-based tasks and authentic learning environments for the development of STEM competencies. Other variables, including logical thinking, technology utilisation, problem-based learning, and activity intensity, were reported with less frequency but nonetheless demonstrated statistical significance in particular subgroups. Their impact appears to be context-dependent, possibly influenced by individual learner characteristics or the nature of the pedagogical strategies employed.

6. Discussion and Conclusion

The study identified several variables that demonstrated strong associations with the ability of Generation Z students to integrate STEM knowledge, particularly among those enrolled in tourism and hospitality faculties, where the curriculum necessitates practical knowledge integration and creative experiential design. Three primary clusters of influential variables emerged.

Firstly, the strongest correlation was observed for Learner Engagement (r = 0.669), underscoring its pivotal role in the learning processes of modern students. Generation Z learners, often termed “Digital Natives,” tend to prefer active and practical forms of engagement. This result aligns with Fredricks et al. (2004), who emphasised engagement as a determinant in the acquisition and application of integrated knowledge, especially within frameworks advocating for active and experiential learning. In addition, Activity Intensity (r = 0.578) and Perceived Value (r = 0.554) were also significant, suggesting that the depth and perceived relevance of learning activities are more impactful than mere participation. This aligns with constructivist principles which posit that learners construct knowledge from meaningful experiences within their specific contexts (Bransford, Brown & Cocking, 2000). Given the practical nature of tourism and hospitality education, students benefit from engaging in authentic experiences that cultivate cross-disciplinary understanding.

Secondly, Experiential Learning (r = 0.557) and Project-Based Learning (r = 0.514) emerged as particularly well-suited for Generation Z learners, especially in professionally oriented programmes. These approaches foster critical competencies such as planning, problem-solving, and intercultural communication. This is consistent with Kolb (2014) experiential learning theory, which posits that meaningful learning occurs through iterative cycles of experience, reflection, conceptualisation, and experimentation. These methods are foundational to cultivating critical thinking and collaborative abilities, both central to the 21st-century skillset. Moreover, this corresponds with the STEM education framework, which prioritises the integration of science, technology, engineering, and mathematics with real-world contexts. The findings also reflect the learning preferences of Generation Z students, who seek educational experiences that are practical, challenging, and relevant to professional environments (Sakdapat et al., 2024; Seemiller & Grace, 2016). These students favour learning approaches that transcend rote memorisation, particularly within industries requiring the convergence of artistic and scientific competencies (Schweingruber, Pearson & Honey, 2014).

Thirdly, the data indicated that the use of technology positively correlates with both project-based and experiential learning methodologies. This is consistent with Barron and Darling-Hammond (2008), who observed that integrating technology into project-based learning enhances interdisciplinary understanding and deepens learning outcomes. Crompton (2023) also highlighted that learners in contemporary digital environments function as "knowledge constructors" and "innovative designers," employing technology to navigate and solve complex problems. Furthermore, Project-Based Learning showed a stronger relationship with STEM knowledge integration ($r = 0.51$) than Problem-Based Learning ($r = 0.49$), and also correlated strongly with both problem-solving and technological proficiency. This reflects its effectiveness in enhancing analytical thinking and enabling clearer structuring of interdisciplinary content, aligning with the findings of Thomas (2000) and Tal, Krajcik and Blumenfeld (2006), who found project-based learning to be particularly suitable for students in higher education, especially within fields requiring practical knowledge application such as tourism and hospitality. However, a more nuanced analysis revealed that Problem-Based Learning showed weaker correlations with Logical Thinking ($r = 0.21$) and Learner Engagement ($r = 0.28$), which may suggest that students are not yet fully adapted to the open-ended nature of this approach. This highlights the importance of tailoring problem-based activities to match students' foundational skills to optimise learning outcomes.

In the first regression model, variables including Learner Engagement ($\beta = 0.330$, $t = 5.190$, $p < .001$), Perceived Value ($\beta = 0.291$, $t = 3.452$, $p < .001$), and Activity Intensity ($\beta = 0.223$, $t = 2.273$, $p < .001$) significantly predicted STEM knowledge integration, explaining 11.30% of the variance ($R^2 = 0.113$; Adjusted $R^2 = 0.109$). These results reinforce the perspective of Sikandar (2016), who asserted that experiential elements are central to meaningful learning, particularly when learners engage with real-world scenarios. Fredricks et al. (2004) also argued that engagement acts as a bridge between theoretical content and students' lived experiences, supporting integration across STEM disciplines.

The second model, which focused on instructional strategies, demonstrated the highest predictive capacity ($R^2 = 0.338$; Adjusted $R^2 = 0.332$). Significant variables included Experiential Learning ($\beta = 0.352$, $t = 5.821$, $p < .001$), Problem-Based Learning ($\beta = 0.284$, $t = 4.429$, $p < .001$), and Project-Based Learning ($\beta = 0.261$, $t = 2.430$, $p < .001$). These findings substantiate Kolb (2014) model of experiential learning, which involves cycles of experience and reflection leading to conceptual understanding and application, especially relevant for Generation Z's preference for real-world engagement. This also aligns with constructivist theory, which views knowledge as personally constructed through meaningful experiences (Ainscow, 2020; Burman, 2008; Wertsch & Sohmer, 1995), thereby supporting interdisciplinary integration.

The third model examined specific skill sets and demonstrated an explanatory power of 35.70% ($R^2 = 0.357$; Adjusted $R^2 = 0.350$). The most influential variables were Problem-Solving Skills ($\beta = 0.374$, $t = 5.704$, $p < .001$), Teamwork Skills ($\beta = 0.337$, $t = 4.213$, $p < .001$), Logical Thinking ($\beta = 0.299$, $t = 3.152$, $p < .001$), and Technology Skills ($\beta = 0.258$, $t = 2.351$, $p < .001$). These results corroborate the findings of Blair (2016), who highlighted the importance of these core competencies, as identified by the National Academies of Sciences, Engineering, and Medicine, for fostering 21st-century STEM capabilities. The strong impact of teamwork in particular reflects the growing importance of collaborative learning in promoting cross-disciplinary integration (Lavi, Tal & Dori, 2021).

Across subgroup analyses, Experiential Learning and Learner Engagement consistently emerged as key predictors. Their influence was notably strong among first- and second-year students ($\beta = 0.37$), third- and fourth-year students ($\beta =$

0.41), students with internship experience (β = 0.43), and those living independently (β = 0.43). This supports Kolb (2014) assertion that experiential learning fosters interdisciplinary competence, particularly when learners engage in real-world or collaborative learning environments. Learner Engagement's predictive power across subgroups affirms the social constructivist view that interaction and participation are essential for constructing knowledge (Amineh & Asl, 2015).

Problem-Solving Skills and Logical Thinking were significant predictors, especially among students with lower GPAX (≤ 3.00) or no internship experience, indicating that cognitive abilities may compensate for limited field exposure. This is in line with Dori, Mevarech and Baker (2018), who identified these competencies as foundational to STEM learning, beginning with problem identification and solution design. Teamwork Skills were also influential among specific groups such as male students (β = 0.11), upper-level students (β = 0.40), those living with peers (β = 0.41), and part-time workers (β = 0.33). This reinforces the notion that collaborative learning enhances analytical thinking and knowledge exchange, as argued by Johnson and Johnson (2015). Problem-Based Learning, while not a primary predictor across all groups, was notably influential among students working during their studies (β = 0.32), living with friends (β = 0.32), or not employed (β = 0.29). This supports Barrows and Tamblyn (1980) perspective that problem-based methods are effective for learners who are adept at managing real-life responsibilities.

Furthermore, living independently appeared to promote self-directed learning and technology use, especially among students residing in dormitories or with friends. These patterns align with Siemens (2005) Connectivism theory, which highlights the role of networks and digital tools in constructing knowledge. Students with higher GPAX (> 3.00) demonstrated stronger predictive variables, particularly Learner Engagement, Experiential Learning, and Activity Intensity, reflecting proactive learning behaviours. This corresponds with Biggs (1999) view that such learners are more likely to achieve academic success through knowledge integration and reflective application. These findings further confirm Siemens (2005) assertion that learners must be able to navigate information networks and contextualise learning in a digital era.

In fields such as tourism and hospitality, where theory and practice must be integrated, the ability to apply STEM competencies is essential. Students require 21st-century skills such as Critical Thinking and Problem-Solving to evaluate real-world scenarios and make informed decisions. Collaboration and Communication are also vital for interacting with diverse clients and team members (Thornhill-Miller et al., 2023; Vuojärvi, Eriksson & Vartiainen, 2019). These competencies thus serve as the foundation for integrating STEM knowledge in modern service industriesf. Consequently, high-performing students who actively participate in learning are more capable of applying STEM principles to professional contexts and driving innovation. However, it remains essential to support all learners in building connections between academic knowledge and real-world application, particularly in areas such as tourism design, service provision, and sustainable problem-solving in varied environments.

6.1. Limitations

1. Contextual Limitations of the Sample Group: The sample utilised in this study comprised students enrolled in tourism and hospitality programmes across 24

academic institutions. While this group is well-suited for investigating experiential learning and the development of 21st-century competencies, the findings may not be readily transferable to students in other academic disciplines, particularly those operating within different pedagogical or curricular environments.

2. Methodological Limitations: This research adopted a quantitative approach, employing structured questionnaires as the main data collection instrument. Although this method facilitates robust statistical analysis, it presents inherent limitations in exploring the nuanced dimensions of students' attitudes, depth of understanding, and internal motivation, which are often better captured through qualitative inquiry.
3. Challenges in Measuring Abstract Variables: Several constructs examined in this study, such as the perceived value of experiential learning and levels of learner engagement, are inherently subjective. Despite efforts to ensure validity and reliability, interpretations of these variables are likely to vary among participants, potentially influencing the consistency and precision of the responses.
4. Temporal Limitations of Data: The study employed a cross-sectional design, with data gathered at a single point in time. Consequently, the research does not account for longitudinal developments in skills or behavioural changes. Furthermore, the design restricts the capacity to draw definitive conclusions regarding causal relationships between variables.
5. Influence of Uncontrolled External Variables: While the research considered a wide range of STEM-related factors, it was not feasible to fully account for all external influences that may affect learning behaviours. Elements such as instructional methods, previous educational experiences, personality traits, learning environments, and intrinsic motivation were beyond the scope of this study and may have introduced unmeasured variability into the findings.

6.2. Future Research Directions

1. This study was confined to a sample of students enrolled in tourism and hospitality programmes, which may possess distinctive curricular and pedagogical characteristics that are not reflective of other faculties or academic disciplines. As such, the generalisability of the findings is limited. Future investigations are encouraged to adopt more inclusive sampling strategies, involving cross-faculty students from multiple institutions nationwide. Such comparative approaches could facilitate a broader understanding of STEM learning strategies across diverse academic and professional contexts, ultimately contributing to the formulation of discipline-specific STEM integration models.
2. In light of the study's findings, which identified learner engagement, activity intensity, and experiential learning as key contributors to STEM knowledge integration, subsequent research should prioritise the design and development of integrated STEM instructional models tailored to the learning preferences of Generation Z students. Instructional design frameworks such as the ADDIE model or TPACK could be utilised to construct learning activities that incorporate technological tools, critical thinking, and experiential components. These models should be systematically evaluated using experimental or quasi-experimental research designs to determine their effectiveness and practical applicability.

3. Although the current study examined the direct relationships between selected variables and STEM integration capability, it did not investigate the potential mediating or moderating roles of psychological constructs such as self-efficacy, learning motivation, or intrinsic drive. Future research should adopt advanced statistical methods such as Structural Equation Modelling (SEM) or Multilevel Modelling to uncover the underlying mechanisms that influence the learning process, thereby providing a more comprehensive understanding of the interplay among various cognitive and contextual factors.
4. Considering that Generation Z students are digital natives accustomed to immersive technological environments, future studies should investigate the impact of factors such as digital literacy, artificial intelligence-enhanced learning, and personalised learning systems on STEM integration. Examining the application of digital literacy in particular could yield valuable insights into how learners utilise technology to enhance learning quality and prepare for technology-driven careers, especially in the evolving tourism and hospitality sectors.
5. While this study employed a quantitative methodology that enabled the identification of statistically significant relationships among variables, it offered limited insights into the subjective experiences, thought processes, and personal interpretations of students engaging in STEM learning. Future research should incorporate qualitative methods, such as in-depth interviews, focus group discussions, or ethnographic approaches, to better capture students' authentic experiences.

6.3. Acknowledgement

The research would like to express our sincere gratitude to the executives of the Ministry of Higher Education, Science, Research and Innovation for their policy data support and assistance in coordinating with relevant agencies. We are also grateful to the faculty members from all 24 universities across Thailand's Faculties of Tourism and Hospitality for their full cooperation in field data collection. Their invaluable advice and information were instrumental in shaping our future research directions. Furthermore, their permission to apply these research findings to the same sample group in a second phase of research is a significant contribution to advancing Thailand's education system, enabling more progressive, modern, and sustainable in the long term.

We would like to express our appreciation to all students who voluntarily participated in completing the questionnaires. Your data is incredibly valuable for analyzing and synthesizing findings on STEM knowledge integration among Generation Z students within the context of tourism and hospitality fields. We are also grateful to all personnel who supported the research process at every stage. The research findings can be used to improve teaching and learning management, enhance experiential activities, and strengthen essential 21st - century skills. Moreover, this research provides crucial policy insights for firmly elevating the quality of higher education nationwide.

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