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The Impact of Sustainability Education Mindset and Project Management Skills on Filipino Gen Z Pre-service Science Educators' Innovative Pedagogical Disposition

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Abstract

The emergence of Generation Z as future professional teachers is reshaping the educational landscape, particularly within science education. Despite their increasing presence in pre-service teacher training, limited scholarship exists on their cognitive, affective, and psychomotor dispositions, especially within developing nations of the Global South. Considering their neoliberal orientations and their pivotal role in realising Sustainable Development Goal (SDG) 4 on Quality Education, this study examined how Sustainability Education Mindset (SEM) and Project Management Skills (PMS) influence their Innovative Pedagogical Disposition (IPD). Employing a quantitative design with bivariate (correlation) and multivariate (multiple regression) analyses, the study involved 141 Gen Z pre-service science teachers across key regions in the Philippines who completed the *robotfoto* and standardised instruments. Results revealed significant positive associations between several SEM and PMS sub-dimensions, although some pairings showed inverse relationships, reflecting the nuanced and multifaceted nature of their professional formation. Notably, SEM dimensions such as *Democratic Education* and *Inclusiveness in Education*, alongside PMS components like *Communication Skills* and *Managerial Competences*, emerged as significant positive predictors of multiple IPD sub-dimensions. Theoretically, the findings advance understanding of how sustainability-oriented mindsets and budding managerial proficiencies coalesce to shape innovative pedagogical tendencies among emerging science educators. Practically, the study underscores the necessity of embedding sustainability and project-based skill development in teacher education curricula to nurture Gen Z educators as agents of pedagogical innovation and dynamic sustainability.

***Keywords*:** sustainability education, project management, innovative pedagogy, Gen Z, science educator

1. Introduction

The emergence of Generation Z (*Henceforth* "***Gen Z"***), a demographic born between 1997 and 2012 (Dimock, 2019), signals a transformative shift within contemporary educational organizations. As the newest entrants to the teaching workforce, with many of whom are still

undergoing pre-service education training, they are poised to play an indispensable role in shaping the future of teaching and learning delivery systems. Scholars contend that the cohort's capacity to drive innovation and sustain progress necessitates an in-depth understanding of their '*Ethos*' (Beliefs) and '*Personae*' (Identity) as future professional teachers (Obmerga, 2025). In this regard, academic institutions must proactively brace for their peculiar cognitive, affective, and behavioural attributes to optimise their pedagogical prowess. Recent research has shown that their emerging teaching roles, anchored on efficient task and technological management, align with the transdisciplinary mandates of the United Nations' (UN) Sustainable Development Goals (SDG) no. 4: *Quality Education*, positioning them as key actors in advancing educational equity and excellence in modern-day classrooms (Chan & Lee, 2023).

By and large, as schools strive to contribute to the aforesaid development agenda, pre-service teachers are increasingly being immersed in sustainability-centric frontiers, aiming to cultivate responsible and forward-thinking educators (Obmerga & Yambao, 2025). Among the academic disciplines, science education provides a fertile ground for embedding the principles of Education for Sustainable Development (ESD), fostering a holistic understanding of sustainability challenges and its coveted solutions (Kyle, 2020). Given that Gen Z pre-service science educators will soon constitute the dynamic talent pool of the teaching profession, it is crucial to assess their potential contributions to sustainable teaching ventures. The age-group's ability to integrate sustainability and how they weave those practices into their pedagogies not just ascertain their instructional plan's fruition, but it can also significantly shape the future landscape of science education (Anwar et al., 2020).

Despite the growing emphasis on educational sustainability in recent years, there is a dearth of perspectives about how Gen Z pre-service educators operationalise the facets of sustainability in their classroom-related undertakings. The Sustainability Education Mindset (***"SEM"***) in this inquiry refers to the cognitive attributes of such novice educators towards integrating sustainability into their innovative instructional perspectives. Understanding their SEM is vital in assessing their priorities concerning sustainability and how these translate into their skill-set as teachers. However, performative SEM alone does not guarantee effective implementation without requisite skills to actualise such notions (Çam-Tosun & Söğüt, 2024; Đajić et al., 2024). This brings to the fore the critical role of examining their Project Management Skills (***"PMS"***) to ensure the execution of sustainability-driven instructional ini9tiatives. PMS is operationalised in this study as the psychomotor ability to systematically oversee and painstakingly translate ideas under the larger purview of developing their dynamic teaching attributes.

Whether inward-tending or outside-looking, given the stereotypical characterizations associated with the generation of interest concerning intermittent compliance and nonlinear tendencies (Mahapatra et al., 2022), coupled with their entitled, impulsive, and narrow-minded archetypes as a collective (Lazar et al., 2023), such notoriety and reluctance to conform to rigid academic structures and stringent demands of science education raises intriguing questions about the interplay of their SEM and PMS into their Innovative Pedagogical Disposition (***"IPD"***). This study views IPD as an affective construct encompassing 21st century soft skills essential for setting the stage for a student-centred learning milieu. Given its potential for an enduring impact, their IPD becomes the critical outcome variable that could profoundly shape Gen Z's instructional practices. Such a purposeful classroom agenda, borne out of their intrinsic motivation to facilitate dynamic lessons, will give them a wider latitude of approaches to

improve their classroom's learning climate (Jerusalem, 2020) and with the overarching goal of molding 'sustainability citizens' (Fujii & Lee, 2024, p. 3) in the future.

Albeit empirical efforts on Gen Z science educators are steadily expanding (Van Katwijk et al., 2021), there remains a significant gap in the literature that places their cognitive leanings and psychomotor potentials into the watch glass, along with their affective dispositions, as teachers-in-training. To date, no inquiry has explicitly investigated the trifocal lenses of SEM, PMS, and IPD, particularly in the context of a developing nation in the Global South, such as the Philippines. This quantitative inquiry generally purported to examine which among the sub-dimensions of SEM and PMS, respectively, impacts the sub-dimensions of IPD, ultimately uncovering preliminary insights of an undervalued yet promising aspect of the demographic's professional formation. Furthermore, as the apparent focus of educational inquiries in the coming years, a nuanced appreciation of how they operate as would-be educators could robustly ignite the theoretical and practical discourse on contemporary pre-service science educator preparation and their conduct of innovative pedagogies against the backdrop of sustainable frame of mind and project regulatory actions. Considering such assertions, this inquiry sought to answer the following Research Questions (***"RQs"***):

1. What is the respondents' performance profile in the specific sub-dimensions of the independent variables (SEM and PMS) and dependent variable (IPD)?
2. Is there a correlation that exists between the sub-dimensions of the independent variables: SEM and PMS?
3. Which among the sub-dimensions of (a) SEM and (b) PMS impact the respondents' IPD sub-dimensions?

2. Literature Review and Hypotheses Development

2.1. The Cognitive and Psychomotor Attributes of Novice Science Educators

The preparation of prospective science educators necessitates a nuanced appreciation of their cognitive and psychomotor competencies, particularly in the realm of sustainability ideation and project execution. Scholars posit that cognitive structures amplify the way teachers conceptualise sustainability (McNaughton, 2012), while psychomotor proficiency dictates their ability to materialise these notions into tangible classroom initiatives (Kalsoom & Qureshi, 2021). By the same token, recent research has shown that while mental learnings with sustainability facets is essential, the absence of sound project management skills may hinder the successful approaches and strategies (Rodríguez-Montequín et al., 2018). The relationship between SEM and PMS among Gen Z pre-service science educators remain a blank spot in the literature, hence it is imperative to examine whether these domains exhibit a meaningful association, as their interplay may define the effectiveness of their future science instructional practices.

Null Hypothesis (H_0) 1: There is no significant correlation between the SEM and PMS of Filipino Gen Z pre-service science educators.

Alternative Hypothesis (H_a) 1: There is a significant correlation between the SEM and PMS of Gen Z pre-service science educators.

2.2. The Sustainability Education Mindset, Innovative Pedagogical Disposition, and Gen Z Educators

The SEM serves as a cognitive wellspring for pre-service science educators, shaping their instructional philosophies and commitment to integrating sustainability concepts into pedagogy. Recent literature trends have delineated that teachers who internalise sustainability principles exhibit higher levels of pedagogical innovation potential (McCunn et al., 2020). However, some scholars contend that mindset alone does not translate into pedagogical transformation unless reinforced by a deeply-seated affective propeller of professional practices (Fix et al., 2021). Given that Gen Z educators are digital natives known for their unconventional approaches to teaching and learning (Chan & Lee, 2023), it is crucial to determine whether their SEM influences their IPD. By empirically examining this linkage, the inquiry will unfurl the hidden terrain constituting the influence of specific mindset-driven agenda on pedagogical soft skills that drives the perspectives of the upcoming cohort of professional science educators.

Null Hypothesis (H_0) 2: SEM sub-dimensions do not significantly impact the IPD of Filipino Gen Z pre-service science educators.

Alternative Hypothesis (H_a) 2: One to two SEM sub-dimensions significantly impact the IPD of Filipino Gen Z pre-service science educators.

2.3. The Project Management Skills, Innovative Pedagogical Disposition, and Gen Z Educators

The PMS are pivotal in translating educational concepts into systematic and executable teaching avenues. Scholars argue that while sustainability mindset provides the cognitive impetus for innovation, it is the inherent ability to organise, implement, and sustain projects that determines the enduring pedagogical effectiveness (Toledo et al., 2021). In the same vein, recent research underscores that novice educators often struggle with project execution due to limited experience in managing instructional affairs (Sela & Harel, 2018). Considering the unconventional schema and erratic behaviours of the Gen Z as a demographic (Dimock, 2019), they are predisposed to adaptive yet unstructured learning methodologies. The cohort's PMS may serve as the critical determinant of their affective soft skills relating to innovative pedagogies. As this scholarly viewpoint remains uncharted, understanding whether effective PMS fosters a tempered IPD is crucial to uncover if the progressive generation can subscribe into stratified and strategic behavioural scaffoldings.

Null Hypothesis (H_0) 3: PMS sub-dimensions do not significantly impact the IPD of Filipino Gen Z pre-service science educators.

Alternative Hypothesis (H_a) 3: One to two PMS sub-dimensions significantly impact the IDP of Filipino Gen Z pre-service science educators.

3. Theoretical Framework

Anchored in Ajzen's (1985) Theory of Planned Behaviour (**"*TPB*"**), this study elucidates the dynamic interplay among SEM, PMS, and IPD within the milieu of Filipino Gen Z pre-service science educators. TPB posits that intention-driven actions stem from the alignment of attitudes, subjective norms, and perceived behavioural control; constructs that mirror the cognitive, affective, and conative dimensions shaping an educator's professional agency. Within this frame, SEM signifies the cognitive strand, reflecting educators' beliefs, values, and interpretive

stances toward sustainability-oriented instruction. PMS embodies the conative or behavioural strand, representing the strategic and procedural competence required for the systematic execution of teaching innovations. IPD functions as the affective strand, encompassing both the emotional resilience and the creative adaptability that amplifies 21st century pedagogical practices. This theoretical underpinning situates Gen Z pre-service educators as active constructors of meaning whose cognitive awareness, operational skills, and value-laden dispositions interact to shape their pedagogical intentionality. Through correlational and regression analyses, the framework enabled the mapping of how sustainability-oriented cognition and project management efficacy collectively inform and reinforce innovative pedagogical conduct. Hence, TPB provided a robust explanatory lens for understanding how internalised sustainability beliefs and perceived regulatory capacities converge into purposeful instructional action among emerging science teachers in the contemporary era.

4. Methods

4.1. Research Design

The study employed a quantitative research approach to examine the relationship between SEM and PMS and their impact on IPD among Filipino Gen Z pre-service science educators. Anchored in a correlational-causal research design, the inquiry integrated descriptive and inferential statistical techniques, both bivariate and multivariate in nature. Descriptive statistics characterised respondents' demographic profiles and performance across the study's key constructs. Correlational analysis determined the strength of associations between the SEM and PMS, while multiple regression shed light on the specific sub-dimensions of SEM and PMS that have an impact towards the sub-dimensions of IPD.

4.2. Respondents and Locale

A total of one hundred forty-one (141) respondents participated in this study. Given the use of regression analysis, an *A priori* power analysis (Soper, 2025) was conducted before the data collection to ensure methodological rigor. The parameters were set with an effect size of Cohen's $f^2 = 0.15$, a statistical power of 0.8, and an α level of 0.05. The independent variable with the highest number of predictors, the PMS with five (5) factor dimensions, was considered in determining the minimum required sample size, which was estimated at 127. The final sample (N = 141) exceeded this threshold, reinforcing the study's reliability and validity. This sample size aligns with Hair and colleagues' (2010) recommendation of at least 100 cases for regression models with 3-5 predictors, ensuring stable parameter estimates and enhancing the generalizability of the findings.

The respondents were selected using purposive sampling, adhering to the following pre-set criteria, to wit: (a) natural-born Filipino citizen, (b) belongs to the Gen Z (1997-2012), (c) currently enrolled in the Bachelor of Secondary Education (BSEd), specialising in Science, programme in a Commission on Higher Education (CHED)-recognised private Teacher Education Institutions (**"*TEIs*"**), (d) having firsthand experiences in field study (classroom observations) or actual science teaching as part of their practicum (Year Levels 2-4), (e) possessing prior experience in project-based tasks and assessments during their undergraduate studies, (f) having awareness of sustainability concepts, particularly the UN's SDG no. 4. The inquiry was conducted in the National Capital Region (NCR) and Region IVA:

CALABARZON, two of the key educational, economic, sociocultural, and political hubs in the Philippines. Table 1 summarises the demographic profile of the participants.

4.3. Instrumentation

The inquiry utilised a four-pronged instrument. The first segment captured the respondents' demographic profiles using a *robotfoto*, a Dutch term referring to a biographical sketch of the study participants, comprising checkboxes and blank fields of demographic information (Kelchtermans & Ballet, 2002). The subsequent sections employed standardised instruments with robust psychometric properties, in which the author has sought formal approval through correspondence from its respective original developers to utilise them in this investigation.

The SEM, defined as a cognitive orientation that embodies educators' awareness, values, and commitment towards embedding sustainability principles in teaching and learning contexts, was assessed using the 19-item Sustainable Education Scale (SES; Cronbach's $\alpha = 0.92$) developed by Çam-Tosun and Sögüt (2023), which encompasses four (4) sub-dimensions, namely: *Quality in Education* (***"QE"***), *Inclusiveness in Education* (***"IE"***), *Equality in Education* (***"EE"***), and *Democratic Education* (***"DE"***), rated on a 5-point Likert scale (Strongly Disagree to Strongly Agree). Sample items include: "*There are no differences among public schools in terms of the opportunities provided to the individuals in my country*" and "*Individuals are not discriminated against due to their language, religion, ethnicity, gender, etc. during their education in my country*."

Moreover, the PMS, characterised as a set of procedural and strategic competences enabling educators to plan, organise, and implement instructional initiatives effectively within time, resource, and outcome constraints, was measured using the 45-item Project Manager Skills Scale (PMSS; Cronbach's $\alpha = 0.97$) created by Đajić and associates (2024), which consists of five (5) sub-dimensions, namely: *Communicational Skills* (***"CS"***), *Technical Skills* (***"TS"***), *Technological and Methodological Competences* (***"TMC"***), *Managerial Competences* (***"MC"***), and *Management Style – Leadership* (***"MSL"***), rated on a 5-point Likert scale (Complete Disagreement to Complete Agreement). Representative questions consist of: "*I believe that the project manager's effective verbal communication skills are essential for the project's success*" and "*I believe that the project manager's ability to set deadlines is important for the project's success*."

Lastly, the IPD, described as an affective inclination to adopt, adapt, and sustain creative, reflective, and learner-centred approaches in education, was evaluated utilising the 40-item Teachers' Innovative Strategies Scale (TITSS; Cronbach's $\alpha = 0.93$) by Jerusalem (2020), which includes four (4) subdimensions, namely: *Critical Valuing* (***"CriV"***), *Creative Valuing* (***"CreV"***), *Sociability* (***"S"***), and *Technological Valuing* (***"TV"***), rated on a 4-point Likert scale (Never to Always). The TITSS, originally designed to assess teachers' competencies in innovative pedagogy, was adjusted to emphasise affective dispositions by reframing its sub-dimensions to reflect emotional engagement, values, and intrinsic motivation. Illustrative statements encompass: "*I reflect on teaching/learning problems and learn from experiences*" and "*I manifest courage to try new things in teaching or learning*."

4.4. Data Gathering Procedure

Upon identifying respondents who satisfied the inclusion criteria, the author formally invited them to participate, providing a clear outline of the inquiry's objective and scope. Respondents who consented to join were given a Quick Response (QR) code linked to a Google Form

containing the four-pronged instrument. An embedded Informed Consent Form section was presented at the start of the form, requiring acknowledgement before proceeding with the survey. Explicit assurances of compliance with ethical parameters and the Data Privacy Act of the Philippines were provided. Respondents were extended ample time to complete the questionnaire, ensuring thoughtful responses and strategic instrument retrieval. Accomplished responses were scrutinised for completeness, yielding a 100% response rate. The dataset was then organised for statistical analysis and interpretation.

4.5. Data Analysis

The author utilised the IBM Statistical Package for the Social Sciences (IBM - SPSS) version 25 to build the comprehensive respondent profile, encompassing both demographic and instrument performance dimensions. Inferential analyses included correlation analysis to examine the relationship among the independent variables and for multicollinearity purposes to ensure the independence of the variables. Subsequently, multiple regression analysis was conducted to determine which among the sub-dimensions of SEM and PMS impact the sub-dimensions of IPD. This analytical approach allowed for the insightful isolation of significant predictors in the emerged regression models.

4.6. Ethical Considerations

The inquiry was cleared by Centro Escolar University, Manila – Coursework Publications under protocol code: PRSE352-SY2024-25-2. Apart from securing the Informed Consent Forms before the administration of the four-pronged instrument, the respondents were thoroughly briefed on the study's overarching objective, procedural phases, minimal to zero risk, data management protocols, and strict compliance with privacy and confidentiality. They were also oriented of their right to withdraw from the investigation at any stage without any form of penalty.

5. Results and Discussion

5.1. Description of the Study Respondents

TABLE 1. THE RESPONDENTS' DEMOGRAPHIC PROFILE (N = 141)

Profile Component	f	%	Profile Component	f	%
Age Range (Year Level)			**Pre-service Science Teaching Exposure**		
23–24 (BSEd Sci Level 4)	74	52.50	Junior High School (Gr. 7-10)	76	53.90
21–22 (BSEd Sci Level 3)	65	46.10	Senior High School (Gr. 11-12)	58	41.10
19–20 (BSEd Sci Level 2)	2	2.00	**Other Teaching Assignment**		
Sex			Early Grades (Gr. 1-3)	3	2.10
Male	46	32.60	Middle School (Gr. 4-6)	4	2.80
Female	95	67.40	**Science Subjects Facilitated***		
Philippine Region of Origin			Integrated Science	22	15.60
National Capital Region	76	53.90	Biological Science	65	46.10
IVA: CALABARZON	65	46.10	Physical Science - Chemistry	56	39.70
Respondents' belief if their TEI practices the SDG 4 (QE)			Physical Science - Physics	76	53.90
			Environmental Science	35	24.80
Yes	122	86.50	Earth and Life Science	40	28.40
No	5	3.50	Others	0	0
Uncertain	14	9.90			

Notes: *Multiple Responses; BSEd Sci – Bachelor of Secondary Education major in Science; Gr. – *Grade*; TEI – *Teacher Education Institution*; SDG 4 (QE) – *Sustainable Development Goal no. 4 (Quality Education)*

Source: Constructed by the sole author (2025)

This inquiry tapped into the quantifiable perspectives of 141 pre-service science teachers from private TEIs, with the majority aged 23–24 (52.50%) and 21–22 (46.10%), reflecting a cohort nearing the completion of their undergraduate degrees in secondary education, being at Level 4 and Level 3, respectively. Most respondents were female (67.40%), while 32.60% were male. Over half of the participants originated from the National Capital Region (53.90%), followed closely by those from CALABARZON (46.10%). This regional distribution suggests that the participants were immersed in academic environments with relatively greater access to instructional innovations and sustainability-aligned programmes.

In terms of pre-service teaching experience, most respondents were assigned to Junior High School (53.90%) and Senior High School (41.10%) levels, consistent with the departmentalised structure of science teaching in the Philippines. A strong presence was observed in major science subject areas, particularly Physical Science - Physics (53.90%), Biological Science (46.10%), and Physical Science - Chemistry (39.70%). However, only a few had experiences teaching Environmental Science (24.80%) and Earth and Life Science (28.40%), accentuating a potential gap in exposure to sustainability-focused content. Notably, 86.50% of respondents believed their TEIs actively uphold SDG no. 4 (Quality Education), a promising indicator of institutional alignment with global educational priorities. Still, the presence of uncertainty (9.90%) and disagreement (3.50%) suggests room for more visible and intentional integration of sustainability principles in pre-service science teacher education.

5.2. Exposition of the Statistical Analyses: RQ1: What is the respondents' performance profile in the specific sub-dimensions of the independent variables (SEM and PMS) and dependent variable (IPD)?

5.2.1. Performance Profile Results (Independent Variables)

TABLE 2A. THE RESPONDENTS' PERFORMANCE PROFILE IN THE INDEPENDENT VARIABLES' SUB-DIMENSIONS

The Independent Variables and its Sub-dimensions	N	Min	Max	Mean	Std Dev
Sustainable Education Mindset (SEM)					
Quality in Education (QE)	141	1.50	5.00	3.63	0.65
Inclusiveness in Education (IE)	141	1.20	5.00	3.31	0.84
Equality in Education (EE)	141	1.77	5.00	3.53	0.66
Democratic Education (DE)	141	1.66	5.00	3.63	0.63
Project Management Skills (PMS)					
Communication Skills (CS)	141	2.00	5.00	4.11	0.49
Technical Skills (TS)	141	2.00	5.00	4.22	0.54
Technological and Methodological Competences (TMC)	141	2.00	5.00	4.14	0.51
Managerial Competences (MC)	141	2.00	5.00	4.23	0.52
Management Style – Leadership (MSL)	141	2.00	5.00	4.21	0.50

Source: Own SPSS v.25 calculation and processing of the sole author (2025)

In Table 2A, the respondents' performance profile across the SEM sub-dimensions revealed nuanced perspectives on their engagement with the foundational pillars of sustainability in education. Among the four domains, both QE (M = 3.63, SD = 0.65) and DE (M = 3.63, SD = 0.63) obtained the highest mean scores. This indicates that Filipino pre-service science teachers generally exhibit an emergent orientation towards educational excellence and participatory

approaches in classroom contexts. EE followed closely (M = 3.53, SD = 0.66), while IE registered the lowest mean (M = 3.31, SD = 0.84), suggesting greater variability in respondents' perceptions or application of inclusive practices.

In contrast, respondents displayed consistently high performance across the PMS sub-dimensions. MC (M = 4.23, SD = 0.52) emerged as the most dominant, followed by TS (M = 4.22, SD = 0.54), MSL (M = 4.21, SD = 0.50), TMC (M = 4.14, SD = 0.51), and CS (M = 4.11, SD = 0.49). The uniformly high means with minimal standard deviations reflect a strong self-perception of competence and confidence in managing projects among Filipino pre-service science teachers.

5.2.2. Performance Profile Discussion (Independent Variables)

The results collectively illustrate that Gen Z pre-service science teachers are developing a promising sustainability-oriented mindset, yet certain dimensions warrant pedagogical strengthening. The high mean scores for QE and DE imply a growing appreciation of academic excellence and participatory learning environments, qualities aligned with the pursuit of sustainable education systems (Liou & Rojas, 2022). These tendencies may mirror TEIs increasing emphasis on quality assurance, reflective practice, and collaborative decision-making in instructional design.

However, the relatively lower performance in IE points to persisting challenges in the integration of diversity and equity principles. The higher standard deviation in IE underscores varying levels of exposure to inclusive pedagogies. As Lazar and associates (2023) noted, members of Generation Z often struggle to establish meaningful interpersonal connections within professional environments, a tendency that could impede inclusive teaching attitudes. This disparity also signals potential inadequacies in current teacher preparation programmes, particularly in preparing future educators to handle heterogeneous classrooms effectively. Symaco (2013) earlier emphasised that while access, equity, and participation are central to education policy, translating these principles into inclusive classroom practice remains an ongoing challenge. Limited classroom immersion with learners of differing abilities or cultural backgrounds, as highlighted by Lautenbach and Heyder (2019), may further restrict the internalisation of inclusive values among pre-service teachers. Consequently, embedding more experiential and field-based learning opportunities becomes essential to bridge the gap between theoretical understanding and applied practice in inclusive education.

On the other hand, the consistently high ratings across all PMS sub-dimensions reveal a favourable self-assessment of managerial and organisational capabilities. The strong performance in MC and TS reflects the structural features of many Philippine TEIs, which emphasise project-based learning, internship programmes, and capstone projects that cultivate leadership and coordination skills. These attributes are fundamental to 21st century teaching, wherein project-based, interdisciplinary, and collaborative modalities are increasingly prioritised. Nonetheless, while respondents reported high proficiency in managerial and technical areas, their relatively lower mean in CS suggests that articulation and rapport-building remain areas for development. As Parks (2020) observed, Gen Z's preference for mediated and asynchronous communication may hinder their interpersonal clarity in professional and pedagogical settings. Cultivating effective communicative competence, therefore, requires sustained scaffolding within teacher training curricula; particularly through interactive and collaborative teaching simulations.

Culturally, these findings resonate with Filipino socio-cultural values such as *Pakikipagkapuwa* (interpersonal connectedness) and *Bayanihan* (collective spirit), which, according to Landa-Jocano (2006), underpin cooperative and community-oriented behaviours. Harnessing these indigenous constructs within project-based and sustainability-oriented teacher education frameworks could enhance relational management, teamwork, and leadership capacities among pre-service science teachers. From a policy perspective, the data imply that sustainability and project management education should be more systematically integrated into teacher preparation programmes. Embedding explicit modules on inclusive education, leadership, and collaborative management, anchored on contextual Filipino values, could develop a new generation of Filipino science educators who are not only technically adept but also ethically and socially attuned. Such targeted curricular reforms can bridge micro-level pedagogical practice with macro-level sustainability goals, aligning teacher education with both national development priorities and the broader SDG no. 4 agenda.

5.2.3. Performance Profile Results (Dependent Variable)

TABLE 2B. THE RESPONDENTS' PERFORMANCE PROFILE IN THE DEPENDENT VARIABLES' SUB-DIMENSIONS

The Dependent Variable and its Sub-dimensions	N	Min	Max	Mean	Std Dev
Innovative Pedagogical Disposition (IPD)					
Critical Valuing (CriV)	141	2.00	4.00	3.23	0.41
Creative Valuing (CreV)	141	2.00	4.00	3.24	0.42
Sociability (S)	141	2.00	4.00	3.23	0.39
Technological Valuing (TV)	141	1.62	4.00	3.23	0.44

Source: Own SPSS v.25 calculation and processing of the sole author (2025)

In Table 2B, the respondents' performance profile across the sub-dimensions of IPD revealed a consistently moderate orientation across all constructs. CreV registered the highest mean (M = 3.24, SD = 0.42), CriV (M = 3.23, SD = 0.41), S (M = 3.23, SD = 0.39), and TV (M = 3.23, SD = 0.44). The narrow range of means and standard deviations suggests a relatively uniform level of engagement and competence among respondents, albeit with potential areas for growth in pedagogical inventiveness and transformative practices.

5.2.4. Performance Profile Discussion (Dependent Variable)

The moderate performance across all IPD dimensions indicates that the respondents possess emerging yet underdeveloped innovative capacities. The relatively higher means in CreV and CriV suggest growing awareness of creative and analytical approaches to teaching, core foundations for pedagogical innovation. However, the comparable levels across all domains imply that these dispositions remain at an exploratory stage, needing further cultivation through structured pedagogical experiences.

The modest score in TV underscores a key disjunction between digital fluency and its pedagogical application. While Gen Z is often considered technologically adept, the limited integration of educational technology in Philippine classrooms (Rombaoa, 2019) constrains their capacity to employ technology as an instructional innovation tool. This reflects a need for teacher education curricula to strengthen digital pedagogy through authentic, project-based experiences that encourage the design and implementation of technology-enhanced learning.

Sociocultural influences may also temper innovation. As Dimock (2019) observes, Gen Z's creativity often coexists with contingent sociability, while Filipino value of *Pakikisama* (harmonious interpersonal engagement) (Landa-Jocano, 2006) may discourage risk-taking and nonconformist experimentation in classrooms. These cultural dynamics shape a cautious engagement with innovation rather than overt disruption.

From a practical standpoint, TEIs must embed innovation-focused modules that integrate creativity, criticality, and technology as interdependent competencies. Establishing innovation laboratories, reflective mentorship, and assessment systems that recognise inventive science teaching could further enable Gen Z pre-service science educators to act as transformative agents within sustainability-oriented and technology-driven science education.

5.3. RQ2: Is there a correlation that exists between the sub-dimensions of the independent variables: SEM and PMS?

TABLE 3. THE CORRELATION MATRIX OF THE INDEPENDENT VARIABLES' SUB-DIMENSIONS

	QE	IE	EE	DE	CS	TS	TMC	MC	MSL
QE (SEM)	1								
IE (SEM)	0.73**	1							
EE (SEM)	0.78**	0.82**	1						
DE (SEM)	0.75**	0.76**	0.79**	1					
CS (PMS)	0.10	−1.02	−0.36	0.10	1				
TS (PMS)	−0.03	−2.10*	−1.66*	0.02	−0.91**	1			
TMC (PMS)	0.07	−1.38	−0.66	0.10	0.83**	0.87**	1		
MC (PMS)	−0.02	−2.63**	−1.83*	0.01	0.84**	0.93**	0.87**	1	
MSL (PMS)	−0.02	−2.36**	−1.72*	−0.00	0.86**	0.92**	0.85**	0.93**	1

Notes: * p < .05, ** p < .01

Source: Own SPSS v.25 calculation and processing of the sole author (2025)

5.3.1. Independent Variables' Correlation Results

In Table 3, the correlation analysis was conducted on the sub-dimensions of the independent variables, utilising aggregated scores derived under the assumption of equidistant intervals in the Likert-type response scales. The results among the sub-dimensions of the SEM reveal a cohesive pattern of statistically significant positive correlations, underscoring the conceptual interrelatedness of equity-driven and democratic values concerning sustainability in the worldview of Filipino pre-service science teachers. The highest correlation was observed between EE and IE ($r = 0.82$, $p < .01$), followed by EE and DE ($r = 0.79$, $p < .01$), QE and EE ($r = 0.78$, $p < .01$), and QE and DE ($r = 0.75$, $p < .01$).

Meanwhile, a closer examination of the interrelationships among the sub-dimensions of PMS reveals a constellation of robust positive correlations, underscoring the mutually reinforcing nature of these competencies among Filipino Gen Z pre-service science teachers. Notably, TS displayed very strong associations with TMC ($r = 0.87$, $p < .01$), MC ($r = 0.93$, $p < .01$), and MSL ($r = 0.92$, $p < .01$), while CS significantly correlated with TMC ($r = 0.83$, $p < .01$), MC ($r = 0.84$, $p < .01$), and MSL ($r = 0.86$, $p < .01$).

Moreover, a revealing trend surfaces in the statistically significant negative correlations between SEM and selected PMS sub-dimensions. Specifically, IE negatively correlates with TS ($r = -2.10$,

$p < .05$), MC ($r = -2.63$, $p < .01$), and MSL ($r = -2.36$, $p < .01$). Similarly, EE exhibits inverse relationships with TS ($r = -1.66$, $p < .05$), MC ($r = -1.83$, $p < .05$), and MSL ($r = -1.72$, $p < .05$).

Finally, the non-significant correlations, particularly those between QE and all PMS sub-dimensions, CS ($r = 0.10$), TS ($r = -0.03$), TMC ($r = 0.07$), MC ($r = -0.02$), and MSL ($r = -0.02$), suggest a disconnect between aspirational constructs and actionable competencies. Weak or statistically non-significant relationships were also observed between DE and certain PMS domains (e.g., DE–CS: $r = 0.10$; DE–TS: $r = 0.02$; DE–TMC: $r = 0.10$; DE–MC: $r = 0.01$; DE–MSL: $r = -0.00$).

In light of the results, the null hypothesis (H_0) 1, which claimed no significant correlation between SEM and PMS among Filipino Gen Z pre-service science educators, is rejected. Both significant positive and negative correlations emerged, indicating a nuanced relationship between SEM and PMS. Hence, the alternative hypothesis (H_a) 1 is accepted, confirming the presence of statistically significant associations between the two constructs.

5.3.2. Independent Variables' Correlation Discussion

The strong positive intercorrelations among SEM sub-dimensions indicate that the respondents conceptualise sustainability through interconnected principles of equity, inclusion, and democracy. This coherence reflects a holistic commitment to socially just and learner-centred pedagogies, resonating with the Filipino communal values of *Pagtutulungan* (mutual help) and *Pakikiramdam* (attunement to collective sentiment) (Landa-Jocano, 2006). Such orientation mirrors the Gen Z inclination towards empathetic activism, suggesting that sustainability education is perceived as an ethical and relational endeavour rather than a technical framework (Maila & Pitsoe, 2012). Within science teacher education, this integrative stance is critical, as sustainable pedagogy must be both epistemologically inclusive and ethically grounded (Smith et al., 2022).

Similarly, the strong internal consistency among PMS sub-dimensions suggests that project management competencies among pre-service science teachers develop in synergy. The interplay between technical skills, managerial foresight, and digital proficiency denotes a coherent skill set aligned with contemporary project management frameworks (Li et al., 2020). This reflects the multitasking, technology-driven, and self-directed tendencies of Gen Z learners (Arkhipova et al., 2019; Weber & Keim, 2021). Rooted in *Pananagutan* (accountability) (Landa-Jocano, 2006), such dispositions challenge the stereotype of Gen Z as disengaged or immature (Dimock, 2019), highlighting instead their capacity for ownership and systemic organisation; traits indispensable in managing inquiry-driven science learning environments (Ruhrig & Höttecke, 2015).

However, the negative correlations between selected SEM and PMS sub-dimensions reveal a generational and pedagogical dissonance. The inverse relationship suggests that while inclusivity and equity are valued, these may not directly translate into managerial or technical confidence. This divergence may stem from the fragmented nature of teacher preparation in the Philippines, where affective and ethical dimensions such as *Pagkakaisa* (unity) are cultivated, yet operational skills receive less emphasis (Landa-Jocano, 2006). As Pramana and collaborators (2021) observed, Gen Z's advocacy-oriented idealism often faces challenges when applied within bureaucratic or procedural constraints. This signals a need for curriculum integration where sustainable values and management capacities coexist, allowing teachers to enact ethical principles within institutional realities (Parry & Metzger, 2023).

The absence of significant correlations between QE, DE, and several PMS domains underscores a gap between theoretical orientation and practical competence. This detachment may result from an overemphasis on conceptual ideals in the teacher education curriculum, at the expense of applied project execution. To bridge this, science teacher education must balance idealism with implementational literacy, equipping pre-service teachers to operationalise sustainability beyond rhetoric. Integrating Filipino interpersonal values like *Pakikisama* (harmonious engagement) (Landa-Jocano, 2006) with strategic decision-making skills may help future educators translate sustainable ideals into classroom innovations and community actions (Marangio et al., 2024; Obmerga, 2025).

5.4. RQ3: Which among the sub-dimensions of (a) SEM and (b) PMS impact the respondents' IPD sub-dimensions?

TABLE 4A. THE MULTIPLE REGRESSION MATRIX OF THE SEM AND IPD VARIABLES

Model	Explanatory Variables	β Coefficient	R^2	F	t-value	p-value	VIF
SEM sub-dimensions (IV) as Predictors → Specific IPD sub-dimension (DV)							
Model 1	QE → CriV	0.03	0.03	1.19	0.24	0.81	3.06
	IE → CriV	−0.22			−1.42	0.15	3.63
	EE → CriV	−0.07			−0.41	0.68	4.42
	†**DE → CriV**	0.28			1.85	**0.03***	3.24
Model 2	QE → CreV	0.12	0.08	3.25	0.89	0.37	3.06
	†**IE → CreV**	0.44			2.82	**0.00*****	3.63
	EE → CreV	−0.04			−0.23	0.81	4.42
	†**DE → CreV**	0.37			2.56	**0.01****	3.24
Model 3	†**QE → S**	0.41	0.08	3.09	2.91	**0.00*****	3.06
	†**IE → S**	0.29			−1.91	**0.05***	3.63
	EE → S	−0.20			−1.21	0.23	4.42
	DE → S	0.05			0.35	0.72	3.24
Model 4	QE → TV	0.16	0.06	2.20	1.13	0.25	3.06
	IE → TV	−0.14			−0.93	0.35	3.63
	†**EE → TV**	0.34			−1.96	**0.05***	4.42
	†**DE → TV**	0.31			2.08	**0.03***	3.24

Notes: † Significant Predictor; * p < .05, ** p < .01, ***p < .001

Source: Own SPSS v.25 calculation and processing of the sole author (2025)

5.4.1. Multiple Regression (SEM to IPD) Results

Multicollinearity diagnostics were conducted in both predictor variables prior to the formal regression analyses using Variance Inflation Factor (VIF) determination. All VIF values were found to be below the conventional threshold of 5, indicating an acceptable degree of independence among the variables (Field, 2013). The multiple regression analysis explored the relationships among Likert-scale variables, which were treated as interval-level data, consistent with accepted conventions in academic research methodology. Upon analyses, some predictors were found to be significant while others were not, revealing a differential pattern of influence among the SEM (Models 1 to 4) and PMS (Models 5 to 8) sub-dimensions. Each model offers a distinct analytical lens through which the predictive influence of specific SEM and PMS components on discrete facets of IPD can be discerned. Presenting all models enables a comprehensive portrayal of how cognitive orientations, procedural competences, and affective dispositions interact, rather than conflating them into an aggregated effect.

In Table 4A, the regression models using SEM as predicators collectively produced R^2 values ranging from 0.03 to 0.08, reflecting a modest explanatory power consistent with trends in educational research. In Model 1, only DE significantly predicted CriV ($\beta = 0.28$, $p = 0.03$), explaining 3% of the variance. The remaining predictors—QE, IE, and EE—were non-significant. This suggests that among the four dimensions of the SEM, DE, grounded in participation, shared authority, and learner voice, is most closely associated with the respondents' critical disposition.

In Model 2, two predictors emerged as significant: IE ($\beta = 0.44$, $p < .001$) and DE ($\beta = 0.37$, $p = 0.01$). Together, these predictors accounted for 8% of the variance in CreV. This finding indicates that the respondents tend to demonstrate higher creativity when they value inclusiveness and democracy in their teaching practice. The result emphasises the role of inclusive and participatory pedagogies in fostering innovative and adaptive behaviour among future educators.

For Model 3, both QE ($\beta = 0.41$, $p < .001$) and IE ($\beta = 0.29$, $p = 0.05$) significantly predicted Sociability (S), with the model explaining 8% of the variance. The positive association implies that respondents who value quality and inclusiveness in education are also more likely to engage in collaborative, peer-oriented, and community-based professional behaviour. These results align with the generational characteristics of Gen Z, who are known for their social connectivity and preference for teamwork.

Finally, in Model 4, DE ($\beta = 0.31$, $p = 0.03$) and EE ($\beta = 0.34$, $p = 0.05$) were found to be significant predictors of TV, explaining 6% of the variance. These findings demonstrate that respondents who hold strong democratic and equality-oriented educational values tend to perceive technology as a vehicle for equity and participation. This suggests that sustainability-oriented thinking among pre-service educators extends into their technological perspectives, linking innovation with access and fairness.

In light of the findings, the null hypothesis (H_0) 2 is rejected in favour of the alternative hypothesis (H_a) 2, as at least two sub-dimensions of the SEM, notably DE and IE, significantly influenced the IPD of Filipino Gen Z pre-service science educators. Such predictors underscore the strategic assimilation of sustainability-aligned cognitive orientations into the affective dimensions of pre-service science teacher training, suggesting that attributes such as inclusivity and democracy are not merely abstract ideals but are also emotionally internalised. These dispositions reveal a unique hybridity among the cohort: caring yet cautious, collaborative yet critically assertive, tradition-aware yet future-forward.

5.4.2. Multiple Regression (SEM to IPD) Discussion

The findings collectively illustrate that the SEM modestly influences the IPD of Gen Z pre-service science educators. Across all models, democratic and inclusive orientations consistently emerged as the strongest predictors, underscoring that valuing participation, equality, and learner voice promotes the cultivation of criticality, creativity, sociability, and technological engagement.

The prominence of DE as a recurrent predictor signifies that Gen Z's innovative dispositions are deeply rooted in social consciousness and participatory ethics. This aligns with characterisations of the generation as justice-oriented and reform-driven (Harari et al., 2023; Mahapatra et al., 2022). Within the Filipino cultural milieu, democratic ideals provide a socially acceptable channel for

expressing critique, given the cultural dynamics of *Pakikisama* (harmonious engagement), *Kahihiyan* (a sense of shame), and *Utang na Loob* (debt of gratitude) (Landa-Jocano, 2006).

Similarly, the effects of inclusiveness and quality highlight how creativity and collaboration develop from collective engagement rather than individual effort. These results parallel Dimock's (2019) assertion that Gen Z educators embody adaptability and social problem-solving, particularly in resource-constrained environments. They transform inclusive values into creative acts of pedagogical redesign, reflecting the Filipino trait of being *Malikhain* (creative).

The association of DE and EE with technological engagement further implies that the cohort interprets technology not merely as a science instructional convenience but as an instrument of empowerment and equality (Kim & Lee, 2020; Mahapatra et al., 2022). Having witnessed technological inequities, Gen Z pre-service teachers approach digital learning with an ethical consciousness, linking access and sustainability with social justice imperatives.

Taken together, these insights demonstrate that sustainability-oriented values nurture not only cognitive and creative competencies but also moral and relational dimensions of pedagogy. This suggests that embedding sustainability education within science teacher preparation programmes may cultivate ethically grounded, socially responsive, and innovation-driven educators capable of advancing equity and transformative practice in science education.

TABLE 4B. THE MULTIPLE REGRESSION MATRIX OF THE PMS AND IPD VARIABLES

Model	Explanatory Variables	β Coefficient	R^2	F	t-value	p-value	VIF
PMS sub-dimensions (IV) as Predictors → Specific IPD sub-dimension (DV)							
Model 5	†**CS → CriV**	0.16			0.90	**0.03***	4.37
	TS → CriV	−0.36			−1.33	0.18	4.64
	TMC → CriV	0.09	0.29	11.38	0.58	0.55	4.87
	†**MC → CriV**	0.43			1.75	**0.02***	4.69
	MSL → CriV	0.23			1.04	0.30	4.87
Model 6	CS → CreV	0.15			0.89	0.37	4.37
	†**TS → CreV**	0.52			2.07	**0.04***	4.64
	†**TMC → CreV**	0.33	0.40	18.59	2.27	**0.02***	4.87
	MC → CreV	0.32			1.41	0.16	4.69
	MSL → CreV	0.37			1.79	0.07	4.87
Model 7	†**CS → S**	0.15			0.81	**0.05***	4.37
	TS → S	−0.55			−1.96	0.41	4.64
	TMS → S	0.12	0.26	9.83	0.78	0.43	4.87
	†**MC → S**	0.72			2.86	**0.00*****	4.69
	MSL → S	0.05			0.24	0.80	4.87
Model 8	CS → TV	0.22			1.22	0.22	4.37
	†**TS → TV**	0.57			2.02	**0.04***	4.64
	TMC → TV	0.20	0.25	9.31	1.23	0.22	4.87
	†**MC → TV**	0.52			2.06	**0.04***	4.69
	MSL → TV	0.12			0.55	0.58	4.87

Notes: † Significant Predictor; * p < .05, ** p < .01, ***p < .001

Source: Own SPSS v.25 calculation and processing of the sole author (2025)

5.4.3. Multiple Regression (PMS to IPD) Results

In contrast to the modest effect sizes observed in Table 4A, the regression models in Table 4B demonstrated stronger explanatory power, with R^2 values ranging from 0.25 to 0.40. This

indicates that the behavioural dimension of PMS exerts a more substantial influence on the affective qualities that constitute IPD among the respondents. The acceptable VIF values ruled out multicollinearity concerns, reinforcing the unique contribution of each PMS sub-dimension.

Model 5 yielded an R^2 of 0.29, accounting for nearly a third of the variance in CriV. Two predictors were significant: CS ($\beta = 0.16$, $p = 0.03$) and MC ($\beta = 0.43$, $p = 0.02$). This suggests that clarity in communication and the capacity to coordinate resources and people significantly enhance critical and evaluative engagement among respondents.

Model 6, which accounted for 40% of the variance, exhibited the strongest explanatory power among all PMS–IPD models. Two predictors—TS ($\beta = 0.52$, $p = 0.04$) and TMC ($\beta = 0.33$, $p = 0.02$)—significantly predicted CreV. This indicates that creativity within pedagogical contexts is closely linked with procedural mastery and structured methodological engagement.

Model 7 explained 26% of the variance in S. CS ($\beta = 0.15$, $p = 0.05$) and MC ($\beta = 0.72$, $p < 0.001$) both emerged as significant predictors. These results highlight that interpersonal and managerial competencies are key behavioural anchors in the social functioning of Gen Z educators.

Finally, Model 8 revealed moderate explanatory power ($R^2 = 0.25$). Two predictors were statistically significant in predicting TV: TS ($\beta = 0.57$, $p = 0.04$) and MC ($\beta = 0.52$, $p = 0.04$). These findings imply that technology valuation is strongly associated with both technical mastery and effective management capacity, reflecting the behavioural underpinnings of digital engagement.

Given the statistically significant points uncovered in each model, the study rejects the null hypothesis (H_0) 3, PMS sub-dimensions do not significantly impact the IPD of Filipino Gen Z pre-service science educators, in favour of the alternative hypothesis (H_a) 3. Notably, MC emerged as a consistent predictor, dynamically pairing with CS, TS, and TMC in certain models. These configurations suggest a meaningful convergence between structured execution and relational fluency, wherein action-oriented skills support affective pedagogical orientations that value the intersection of IPD. Such integration points to a composite stance among this generation: decisive yet dialogic, tech-savvy yet socially attuned, methodical yet imaginatively responsive.

5.4.4. Multiple Regression (PMS to IPD) Discussion

The results collectively underscore that Filipino Gen Z pre-service science educators' IPD are more behaviourally than cognitively anchored, as reflected in the notable explanatory power of the PMS–IPD models. In Model 5, the significant contributions of CS and MC to CriV entail that effective articulation and managerial coordination are central to cultivating a reflective and evaluative teaching stance. This resonates with the observation that Gen Z educators, shaped by rapid sociotechnical change, engage with pedagogical dilemmas as moral and systemic challenges rather than mere procedural issues (Dabke, 2018). The salience of MC supports Khadri's (2022) assertion that managerial foresight enables educators to navigate inquiry-based and dynamic science environments with balance and coherence. Filipino value systems, notably *Pananagutan* (accountability) and *Pagpapakatao* (humanistic consciousness) (Landa-Jocano, 2006), reinforce this synergy between behavioural precision and ethical reflexivity.

The high explanatory power of Model 6, where TS and TMC predicted CreV, highlights that creativity in science education is a deliberate, systematic process rather than spontaneous ingenuity. Gen Z science educators operationalise creativity through structured design and iterative practice (Obmerga & Yambao, 2025), aligning with DeHaan's (2009) view of

creativity as both a cognitive and procedural act. This behaviour echoes the Filipino notion of *Diskarte* (resourceful agency), where innovation emerges from disciplined adaptation within constraints (Landa-Jocano, 2006).

Model 7 demonstrated that sociability thrives when communicative clarity and managerial synergy coexist. Teaching, being inherently collaborative, demands interpersonal fluency as a professional competence (Kolleck et al., 2021). In the Filipino collectivist milieu, social harmony is a pedagogical necessity as much as a cultural expectation (Landa-Jocano, 2006). These findings suggest that teacher education programmes should cultivate structured peer collaboration and mentorship systems to translate sociability into institutional cooperation, enhancing professional learning communities (Donnelly & Hume, 2014).

The final model (Model 8) revealed that TS and MC predict TV, suggesting that Gen Z educators' technological engagement stems from behavioural intentionality rather than innate digital fluency (Dimock, 2019). These results echo the principles of Technological Pedagogical Content Knowledge (TPACK) (Canbazoglu-Bilici et al., 2016), emphasising that effective technology integration relies on cumulative and situated practice (Lowell & Moore, 2020). The association of MC with technology use indicates a form of 'visionary pragmatism' (Coles, 2016, p. 19), wherein educators evaluate technology's pedagogical worth against broader equity and inclusion goals. The Filipino ethic of *Pagkalinga* (caring presence) (Landa-Jocano, 2006) further contextualises how technology becomes a tool for relational and transformative learning.

6. The Researcher's Reflexivity

Reflexivity, though more commonly associated with qualitative traditions, was deliberately integrated into this quantitative inquiry to foreground author positionality and epistemic integrity. As a Filipino science teacher formator, the researcher recognises that personal and professional convictions towards transformative, sustainability-oriented education may have informed the interpretive lens applied to the findings. Additionally, the use of standardised instruments originally constructed in Western contexts also invites reflection on issues of cultural validity, as Filipino conceptions of innovation, project management, and sustainability may embody relational and collectivist nuances not fully captured by such tools. Acknowledging these interpretive and contextual boundaries not only strengthens the study's credibility but also situates its statistical outcomes within the ethical responsibility of representing Filipino Gen Z pre-service science educators' lived educational realities with cultural and intellectual fidelity.

7. Conclusion

The pre-service science teacher education among the Gen Z is a significant global concern, garnering scholarly attention for both its pedagogical implications and its potential to shape the future of education. This quantitative study examined the impact of sub-dimensions of SEM and PMS on the multifaceted construct of IPD, with the intention of uncovering preliminary yet actionable insights into areas that remain largely underexplored within the cohort. The respondents' performance profiles, drawn from standardised questionnaires, suggest a critical need for contemporary science teacher education programmes to enhance experiential training on diversity and inclusive pedagogical practices, scaffold reflective dispositions, and integrate tech-savviness with deliberate, equity-centred instructional innovation. Moreover, the correlation analyses

accentuated the imperative for science teacher education to bridge the gap between idealistic aspirations and practical implementation, emphasising the need for alignment between visionary goals and functional literacy to foster educators who are both futuristically minded and adept in project regulation. Lastly, the regression analyses further underscored the nuanced dynamics shaping the pedagogical formation of the respondents. Notably, the significant influence of democratic and inclusive orientations, coupled with communicative and managerial proficiencies, emerged as pivotal in cultivating innovative teaching dispositions. Positioned as key agents of sustainability, these future teachers require targeted formation to bridge mindset, project execution, and innovation in science education. The study's theoretical contributions, practical applications, limitations, and future directions are discussed below.

7.1. Theoretical Contributions

This study offers three (3) notable theoretical contributions. First, while prior research has explored Gen Z's perspectives on contemporary science and non-science teaching and learning, much of the focus has been on microteaching (Menon et al., 2024) and generative Artificial Intelligence (AI) use (Chan & Lee, 2023). This inquiry is among the pioneering efforts to foreground the unexamined dimensions of SEM, PMS, and IPD within the context of Gen Z as active teachers-in-training, thereby expanding the boundaries of current scholarship. Second, a comprehensive review of the extant literature indicates that, within the Philippine and broader Southeast Asian contexts, previous investigations have focused on state certified, in-service Gen Z science educators, particularly in areas such as safe laboratory teaching praxis (Obmerga, 2025) and informal professional learning (Obmerga & Yambao, 2025). In contrast, this study is among the preliminary efforts to tap into the worldview of pre-service science teachers, offering cutting-edge insights into the pre-service science education landscape and capturing the nuanced perspectives of the cohort situated in the Global South. Third, this inquiry introduces a series of regression models that offer empirically grounded frameworks for advancing SEM, PMS, and IPD within the purview of SDG no. 4 (Quality Education). These models highlight both the competencies in need of targeted interventions and the promising developmental pathways that warrant sustained support among the age-group.

7.2. Practical Implications

This inquiry articulates several practical implications that are vital to the reconfiguration of science teacher education in the contemporary, sustainability era. First, the findings offer actionable insights for curriculum designers, programme developers, and policymakers in shaping the holistic formation of Gen Z pre-service teachers. Through the integration of SEM, PMS, and IPD, TEIs can purposefully design learning experiences that foster agency, ethical sensitivity, and adaptive expertise among science educators. Second, the study underscores the importance of acknowledging and harnessing the worldview of Gen Z science teachers-in-training. Their unique orientations towards collaboration, digital fluency, and innovation present both challenges and opportunities for TEIs. Engaging these dispositions early enables institutions to align training designs with evolving professional demands and to nurture educators capable of responding to the moral and environmental imperatives of the 21st century classroom. Third, the regression models derived from the study may serve as diagnostic and developmental tools that allow TEIs to map skill trajectories, identify capacity gaps, and construct targeted interventions. Such evidence-informed frameworks can guide the design of

early professional learning pathways that enhance reflexive pedagogy, futures thinking, and value-driven teaching practice—all central to sustainability-oriented education. Lastly, the implications of this study transcend national boundaries. Its conceptual and empirical insights may be applicable to other communitarian Global South contexts where the integration of sustainability education and innovative pedagogy remains emergent. By promoting culturally responsive, contextually grounded, and generationally attuned teacher preparation, the study contributes to a broader dialogue on how science education can be re-envisioned to advance the SDGs and equip future educators for transformative praxis.

7.3. Limitations and Future Research Directions

This study bears limitations typical of quantitative inquiries. The use of non-probabilistic sampling restricts the external validity of the findings, which should therefore be interpreted as indicative of trends within the sampled regions rather than nationally generalisable. Although the sample size satisfied power analysis requirements, it may not fully represent the demographic and institutional heterogeneity of Filipino Gen Z pre-service science educators. Future replications are encouraged to encompass a broader range of TEIs across the Philippines to enhance representational robustness.

Subsequent research may employ Covariance-Based *Structural Equation Modelling* (CB-SEM) to validate the hypothesised relationships among variables using larger and more diverse datasets. Likewise, the application of Conjoint Analysis (CA) could offer valuable insights into how pre-service science educators prioritise facets of *Sustainability Education Mindset* (SEM), PMS, and IPD, by revealing the implicit trade-offs embedded in their professional reasoning. Complementary qualitative approaches, such as Glaserian grounded theory or Husserlian phenomenology, are also recommended to deepen understanding of the educators' evolving 'lived ESD' (Fujii & Lee, 2024, p. 8), professional identity formation, and pedagogical agency in the age of the SDGs. Finally, future inquiries could explore the intersection of SEM, PMS, and IPD with other emergent variables in science education, such as digital pedagogical technostress, ecological literacy, and ethical sustainability leadership, to construct a more holistic framework for transformative science teacher education and beyond.

References

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (pp. 11–39). Springer. https://doi.org/10.1007/978-3-642-69746-3_2

Anwar, A., Achiraeniwati, E., & Djaohari, A. H. N. (2020). Young people activities in the responsibility of environmental sustainability: Indonesian perspective. *IOP Conference Series: Materials Science and Engineering, 830*(4), 1–5. https://doi.org/10.1088/1757-899x/830/4/042005

Arkhipova M.V., Belova E.E., Gavrikova Y.A., Pleskanyuk T.N., & Arkhipov A.N. (2019). Reaching Generation Z: Attitude toward technology among the newest generation of school students. In E. Popkova & V. Ostrovskaya (Eds.), *Perspectives on the Use of New Information and Communication Technology (ICT) in the Modern Economy*. ISC 2017. Advances in Intelligent Systems and Computing, 726, (pp. 1026–1032). Springer. https://doi.org/10.1007/978-3-319-90835-9_114

Çam-Tosun, F., & Söğüt, S. (2024). Development and validation of a sustainable education scale. *Sustainable Development, 32*(4), 4082–4096. https://doi.org/10.1002/sd.2892

Canbazoglu-Bilici, S., Guzey, S. S., & Yamak, H. (2016). Assessing pre-service science teachers' technological pedagogical content knowledge (TPACK) through observations and lesson plans. *Research in Science & Technological Education, 34*(2), 237–251. https://doi.org/10.1080/02635143.2016.1144050

Chan, C. K. Y., & Lee, K. K. W. (2023). The AI generation gap: Are Gen Z students more interested in adopting generative AI such as ChatGPT in teaching and learning than their Gen X and millennial generation teachers? *Smart Learning Environments, 10*(1), 1–23. https://doi.org/10.1186/s40561-023-00269-3

Coles, R. (2016). *Visionary pragmatism: Radical and ecological democracy in neoliberal times*. Duke University Press.

Dabke, D. (2018). Leadership styles in the VUCA World, Through the eyes of Gen Z. In S. Dhir & Sushil (Eds.), *Flexible Strategies in VUCA Markets. Flexible Systems Management* (pp. 201–211). Springer. https://doi.org/10.1007/978-981-10-8926-8_15

Đajić, M. J., Lalic, D. C., Vujičić, M. D., Stankov, U., Petrovic, M., & Đurić, Ž. (2024). Development and validation of the project manager skills scale (PMSS): An empirical approach. *Heliyon, 10*(3), 1–13. https://doi.org/10.1016/j.heliyon.2024.e25055

DeHaan, R. L. (2009). Teaching creativity and inventive problem solving in science. *CBE—Life Sciences Education, 8*(3), 172–181. https://doi.org/10.1187/cbe.08-12-0081

Dimock, M. (2019). Defining generations: Where millennials end and Generation Z begins. *Pew Research Center*, 1–7. http://www.pewresearch.org/fact-tank/2019/01/17/where-millennials-end-and-generation-z-begins/

Donnelly, D. F., & Hume, A. (2014). Using collaborative technology to enhance pre-service teachers' pedagogical content knowledge in science. *Research in Science & Technological Education, 33*(1), 61–87. https://doi.org/10.1080/02635143.2014.977782

Field, A. (2013). *Discovering statistics using IBM SPSS* (4th ed.). Sage Publications.

Fix, G. M., Rikkerink, M., Ritzen, H. T. M., Pieters, J. M., & Kuiper, W. A. J. M. (2021). Learning within sustainable educational innovation: An analysis of teachers' perceptions and leadership practice. *Journal of Educational Change, 22*(1), 131–145. https://doi.org/10.1007/s10833-020-09410-2

Fujii, H., & Lee, S. K. (2024). *Science education for sustainable development in Asia*. Springer Nature.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Prentice Hall.

Harari, T. T., Sela, Y., & Bareket-Bojmel, L. (2023). Gen Z during the COVID-19 crisis: A comparative analysis of the differences between Gen Z and Gen X in resilience, values and attitudes. *Current Psychology, 42*, 24223–24232. https://doi.org/10.1007/s12144-022-03501-4

Jerusalem, R. Y. (2020). Teachers' innovative teaching strategies: Scale development using exploratory factor analysis. *International Journal of Social Science and Humanities Research, 8*(2), 80–95. https://www.researchpublish.com/papers/teachers-innovative-teaching-strategies-scale-development-using-exploratory-factor-analysis

Kalsoom, Q., & Qureshi, N. (2021). Impact of sustainability-focused learning intervention on teachers' agency to teach for sustainable development. *International Journal of Sustainable Development & World Ecology, 28*(6), 540–552. https://doi.org/10.1080/13504509.2021.1880983

Kelchtermans, G., & Ballet, K. (2002). The micropolitics of teacher induction: A narrative bibliographical study on teacher socializations. *Teaching and Teacher Education, 18*(1), 105–120. https://doi.org/10.1016/S0742-051X(01)00053-1

Khadri, H. O. (2022). Becoming future-proof STEM teachers for enhancing sustainable development: A proposed general framework for capacity-building programs in future studies. *Prospects, 52*, 421–435. https://doi.org/10.1007/s11125-021-09588-0

Kim, J., & Lee, K. S. S. (2020). Conceptual model to predict Filipino teachers' adoption of ICT-based instruction in class: using the UTAUT model. *Asia Pacific Journal of Education, 42*(4), 699–713. https://doi.org/10.1080/02188791.2020.1776213

Kolleck, N., Schuster, J., Hartmann, U., & Gräsel, C. (2021). Teachers' professional collaboration and trust relationships: An inferential social network analysis of teacher teams. *Research in Education, 111*(1), 89– 107. https://doi.org/10.1177/00345237211031585

Kyle, W. C. (2020). Expanding our views of science education to address sustainable development, empowerment, and social transformation. *Disciplinary and Interdisciplinary Science Education Research, 2*(1), 1–9. https://doi.org/10.1186/s43031-019-0018-5

Landa-Jocano, F. (2006). *Filipino value system: A cultural definition*. Punlad Research House.

Lautenbach, F., & Heyder, A. (2019). Changing attitudes to inclusion in preservice teacher education: A systematic review. *Educational Research*, *61*(2), 231–253. https://doi.org/10.1080/00131881.2019.1596035

Lazar, M.-A., Zbuchea, A., & Pînzaru, D. (2023). The emerging Generation Z workforce in the digital world: A literature review on cooperation and transformation. *Proceedings of the International Conference on Business Excellence, 17*(1), 1991–2001. https://doi.org/10.2478/picbe-2023-0175

Li, Y., Sun, T., Shou, Y., & Sun, H. (2020). What makes a competent international project manager in emerging and developing countries? *Project Management Journal, 51*(2), 181–198. https://doi.org/10.1177/8756972820901387

Liou, D. D., & Rojas, L. (2022). Reimagining expectations and rigor in the college classroom amid the global pandemic: Lessons from the field. *About Campus: Enriching the Student Learning Experience*, *26*(6), 8–12. https://doi.org/10.1177/10864822221082694

Lowell, V. L., & Moore, R. L. (2020). Developing practical knowledge and skills of online instructional design students through authentic learning and real-world activities. *TechTrends, 64*(4), 581–590. https://doi.org/10.1007/s11528-020-00518-z

Mahapatra, G. P., Bhullar, N., & Gupta, P. (2022). Gen Z: An emerging phenomenon. *NHRD Network Journal, 15*(2), 246–256. https://doi.org/10.1177/26314541221077137

Maila, M. W., & Pitsoe, V. J. (2012). Globalization, sustainability and ethics: What are the critical links for present and future generations? *Journal of Human Ecology, 40*(1), 43–51. http://krepublishers.com/02-Journals/JHE/JHE-40-0-000-12-Web/JHE-40-1-12-Abst-PDF/JHE-40-1-043-12-2316-Maila-M/JHE-40-1-043-51-12-2316-Maila-M-Tx%5B5%5D.pdf

Marangio, K., Carpendale, J., Cooper, R., & Mansfield, J. (2024). Supporting the development of science pre-service teachers' creativity and critical thinking in secondary science initial teacher education. *Research in Science Education, 54*(1), 65–81. https://doi.org/10.1007/s11165-023-10104-x

McCunn, L. J., Bjornson, A., & Alexander, D. (2020). Teaching sustainability across curricula: Understanding faculty perspectives at Vancouver Island University. *The Curriculum Journal, 31*(3), 557–572. https://doi.org/10.1002/curj.16

McNaughton, M. J. (2012). Implementing Education for Sustainable Development in schools: Learning from teachers' reflections. *Environmental Education Research, 18*(6), 765–782. https://doi.org/10.1080/13504622.2012.665850

Menon, D., Cheng, D.S. & Ngugi, R. (2024). Investigating preservice secondary teachers' understanding and enactment of the standards-based practices during microteaching. *Journal for STEM Education Research, 7*, 63–95. https://doi.org/10.1007/s41979-023-00093-x

Obmerga, M. E. (2025). The impact of design thinking and innovative work behaviours on Filipino Gen Z novice science educators' safe laboratory teaching praxis. *Southeast Asian Journal of STEM Education, 5*(1), 58–72. https://www.seameo-stemed.org/wp-content/uploads/2023/12/SAJSE-Vol5-No1_Jan-2025.pdf

Obmerga, M. E., & Yambao, F. M. P. (2025). Understanding the early impacts of school mentors' ethics of care on Filipino Gen Z novice science educators' informal professional learning. *GILE Journal of Skills Development, 5*(1), 67–91. https://doi.org/10.52398/gjsd.2025.v5.i1.pp67-91

Parks, E. S. (2020). Listening across the ages: Measuring generational listening differences with the LCI-R. *International Journal of Listening*, *36*(1), 20–30. https://doi.org/10.1080/10904018.2020.1748503

Parry, S., & Metzger, E. (2023). Barriers to learning for sustainability: A teacher perspective. *Sustainable Earth Reviews, 6*(1), 1–11. https://doi.org/10.1186/s42055-022-00050-3

Pramana, H. P., Hastjarjo, S., & Sudarmo (2021). Millennial and Gen Z perspective towards eco-office campaign implementation in public sector. *IOP Conference Series: Earth and Environmental Science, 905*(1), 1–6. https://doi.org/10.1088/1755-1315/905/1/012122

Rodríguez-Montequín, V., Villanueva-Balsera, J., Cousillas-Fernández, S. M., & Ortega-Fernández, F. (2018). Exploring project complexity through project failure factors: Analysis of cluster patterns using self-organizing maps. *Complexity, 2018*, 1–17. https://doi.org/10.1155/2018/9496731

Rombaoa, J. S. J. (2019). The cost of technology integration on Filipino families with children enrolled in public schools. *Asia Pacific Education Review*, *20*(2), 239–248. https://doi.org/10.1007/s12564-019-09597-x

Ruhrig, J., & Höttecke, D. (2015). Components of science teachers' professional competence and their orientational frameworks when dealing with uncertain evidence in science teaching. *International Journal of Science and Mathematics Education, 13*(2), 447–465. https://doi.org/10.1007/s10763-015-9628-3

Sela, O., & Harel, M. (2018). 'You have to prove yourself, initiate projects, be active': The role of novice teachers in their own induction process. *Professional Development in Education, 45*(2), 190–204. https://doi.org/10.1080/19415257.2018.1441173

Smith, T., Avraamidou, L., & Adams, J. D. (2022). Culturally relevant/responsive and sustaining pedagogies in science education: theoretical perspectives and curriculum implications. *Cultural Studies of Science Education, 17*(3), 637–660. https://doi.org/10.1007/s11422-021-10082-4

Soper, D. S. (2025). *A-Priori Sample Size Calculator for Multiple Regression* (Version 4). Free Statistics Calculators [Web-based Software]. https://www.danielsoper.com/statcalc/calculator.aspx?id=1

Symaco, L. P. (2013). Geographies of social exclusion: Education access in the Philippines. *Comparative Education*, *49*(3), 361–373. https://doi.org/10.1080/03050068.2013.803784

Toledo, R. F. de, Farias Filho, J. R. de, Castro, H. C. G. A. de, Putnik, G. D., & Silva, L. E. da. (2021). Is the incorporation of sustainability issues and Sustainable Development Goals in project management a catalyst for sustainable project delivery? *International Journal of Sustainable Development & World Ecology, 28*(8), 733–743. https://doi.org/10.1080/13504509.2021.1888816

Van Katwijk, L., Jansen, E., & Van Veen, K. (2021). Pre-service teacher research: A way to future-proof teachers? *European Journal of Teacher Education, 46*(3), 435–455. https://doi.org/10.1080/02619768.2021.1928070

Weber, K. M., & Keim, H. (2021). Meeting the needs of Generation Z college students through out-of-class interactions. *About Campus: Enriching the Student Learning Experience, 26*(2), 10–16. https://doi.org/10.1177/1086482220971272

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For studies involving human participants, the authors confirm that the research complied with relevant institutional and national ethical standards. Ethical approval was obtained where required, and informed consent was secured from all participants prior to data collection. If ethical approval was not required, the authors confirm that the study adhered to applicable ethical guidelines.

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