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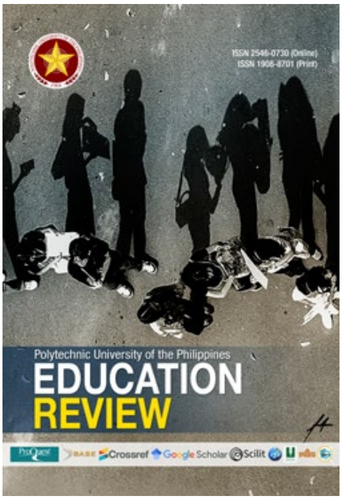

Sensemaking of the Filipino Gen Z Pre-service Science Teachers' Sustainability Education Mindset: An Exploratory Factor Analysis

Marwin E. Obmerga, Ph.D.[1, 2], **Dennis G. Caballes, Ph.D.**[1, 3]
[1] Graduate School, Centro Escolar University, San Miguel, Manila, Philippines
[2] Institute of Education, Far Eastern University, Sampaloc, Manila, Philippines
[3] Office of the Assistant Vice President for Academic Affairs, City University of Pasay, Pasay, Philippines
[4] mobmerga.phd@gmail.com
[5] dgcaballes@ceu.edu.ph

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Sensemaking of the Filipino Gen Z Pre-service Science Teachers' Sustainability Education Mindset: An Exploratory Factor Analysis

Marwin E. Obmerga, Ph.D.[1, 2, 4], **Dennis G. Caballes, Ph.D.**[1, 3, 5]
[1] Graduate School, Centro Escolar University, San Miguel, Manila, Philippines
[2] Institute of Education, Far Eastern University, Sampaloc, Manila, Philippines
[3] Office of the Assistant Vice President for Academic Affairs, City University of Pasay, Pasay, Philippines
[4] mobmerga.phd@gmail.com
[5] dgcaballes@ceu.edu.ph

Abstract

Generation Z educators are increasingly entering the teaching profession, yet their sustainability-related cognitive orientations remain largely unexamined. Mindset, as a construct of educational psychology, encapsulates one's ingrained ways of thinking and valuing. As future science teachers, their mindset toward sustainability has the potential to influence how Education for Sustainable Development is internalised and contextualised in contemporary science classrooms. Understanding how they perceive sustainability may strengthen efforts in cultivating prudent science educators who are responsive to global and local educational challenges. This quantitative inquiry explored the Sustainability Education Mindset (SEM) of Filipino Gen Z pre-service science teachers using the 19-item Sustainable Education Scale developed by Çam-Tosun and Söğüt (2024). A total of 141 respondents participated in the study. Through Exploratory Factor Analysis, three (3) distinct yet interrelated SEM factor dimensions emerged: Reflective Thinking (Looking Back), Systems Thinking (Looking Within), and Futures Thinking (Looking Forward). These newly surfaced components offer deeper insights into the cohort's dynamic and sensible engagement with sustainability. Theoretically, the study contributes to the growing body of literature on cognitive orientations of future science teachers in the Global South. Practically, the findings illuminate the actionable focal points for science teacher preparation programmes, particularly in scaffolding reflective, systemic, and futuristic dispositions.

Keywords: Exploratory Factor Analysis, Generation Z, Sustainability Education Mindset, Pre-service Science Teachers

INTRODUCTION

The way pre-service teachers think fundamentally shapes how they facilitate classes and adapt to the shifting demands of the teaching profession (Brugar et al., 2023). Mindset, as espoused by Dweck (2006), is tagged as a cognitive framework that influences motivation, perception, and behaviour, guiding individuals on how to respond to challenges and opportunities. Ngan and Hercz (2023) underscored that the teachers'

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cognitive orientations are instrumental in influencing and shaping the conceptual and pedagogical foundations of educational paradigms and initiatives. In the last decade, mindset-probing and perception-determination types of inquiries have gained increasing scholarly traction as a determinant of how education-borne professionals engage with complex academic responsibilities (Obmerga & de Guzman, 2024; González et al., 2014). In the context of sustainability education (*Hereinafter referred to* as ***"SE"***), the parlance of mindset refers not only to one's beliefs and preconceived notions, but also to a dynamic cognizance that shapes how evolving professional, environmental, socio-cultural, and ethico-moral challenges are understood and acted upon (Griswold, 2017). As global imperatives, such as the United Nations' Sustainable Development Goals (***"SDG"***), continue to redefine educational priorities, especially the fourth goal about *Quality Education*, there is a growing need to examine how professional teachers internalise SE frontiers (Khadri, 2022). Among the most critical yet severely understudied cohorts in such an endeavour are the Generation Z (***"Gen Z"***) teachers.

Gen Z, broadly encompassing individuals born between 1997 and 2012 (Dimock, 2019), is entering the teaching profession with distinct epistemological stances shaped by digital immersion, operational pragmatism, and civic engagement (Obmerga, 2025). Scholars argue that their formative years have been marked by rapid technological changes, climate change apprehension, and the rising radical social consciousness (Schroth, 2019). As these future professional teachers begin formal preparations for their in-service teaching practice, their evolving identities and cognitive dispositions offer a preliminary generational understanding through which sustainability purview can be interpreted and enacted upon. Obmerga and Yambao (2025) averred that their professional learning viewpoints, rooted in immediacy, adaptability, and cohesiveness, align with the pedagogical demands of sustainability, particularly within the interdisciplinary and solution-oriented landscape of education.

Whether inward-tending or outside-looking, among educational disciplines, science education holds a unique position in addressing sustainability imperatives (Kyle, 2020). Recent research has suggested that it inherently integrates empirical reasoning, critical inquiry, and delves into natural and social systems; interdisciplinary components essential to advancing sustainability goals (Tosun, 2024). Unlike other fields, science education has the innate capacity to directly engage 21st century learners with the technological, ethical, and ecological dimensions of sustainability through data-informed decision-making and problem-based learning (Alkair et al., 2023). The entry of Gen Z into this discipline, however, is not without its challenges. Barhate and Dirani (2022) posited that despite their high career aspirations, their cognitive and behavioural inclinations are typically beset with digital saturation, high variability, and peculiar socio-emotional patterns, thus making it difficult for organisations to predict how they will internalise and apply sustainability principles. Without a grounded understanding of how this cohort perceives sustainability in the science education context, there is a risk of overlooking key opportunities for transformative change that such future strategic actors in the field of education ought to propagate.

Additionally, recent international and interdisciplinary scholarship on SE has increasingly examined how emerging generations conceptualise and enact sustainability-oriented thinking, offering useful comparative insight for contextualising Filipino Gen Z pre-service science teachers' mindset. Scholarly studies in Europe (Wolak-Tuzimek et al., 2025; Ribeiro et al, 2025), for instance, revealed that Gen Z cohorts tend to demonstrate heightened ecological awareness yet vary in their behavioural commitment depending on institutional support and its curricular mandate. In Asian contexts, inquiries involving university students indicate strong pro-sustainability dispositions but identify persistent gaps in systems thinking, collaborative problem-solving, and the translation of values into practice, particularly within teacher education settings (Radzi et al., 2025). Outside the education sector, research involving Gen Z similarly underscores a pronounced preference for ethical, socially responsible, and environmentally conscious decision-making, though such predispositions remain vaguely operationalised longitudinally (Raman et al., 2024). Within the Philippine setting and relating to the present inquiry, Obmerga (2026) contributes pioneering evidence by mapping the impact of SEM of Filipino Gen Z pre-service science teachers, along with project management competencies, into their innovative pedagogical dispositions. These comparative insights highlight both global convergences and contextual divergences, underscoring the need for deeper empirical scrutiny into how Filipino Gen Z pre-service science teachers interpret, internalise, and enact sustainability within science education.

To date, however, empirical inquiries into how future science teachers perceive SE remain scarce. The recent psychometric development of the Sustainable Education Scale (**"*SES*"**) by Çam-Tosun and Söğüt (2024) in the Turkish milieu offers a promising starting point. To elucidate further, the instrument captured the teachers' orientations toward sustainability across various domains. Yet, the tool was constructed from a sample composed largely of in-service, non-science exclusive teachers from the older generations, many of whom hold graduate degrees. This set of demographic attributes raises questions about its applicability to younger and progressive age-groups who may view sustainability through a different ontological and experiential lens. Such a potential dissonance necessitates a closer examination of the instrument's dimensionality when applied to Gen Z pre-service science teachers, whose perspectives have yet to be fully articulated in the educational codified body of knowledge.

This study sought to contribute to the literature by rethinking the SE parameters, conceptualised by Çam-Tosun and Söğüt (2024), through Exploratory Factor Analysis (**"*EFA*"**). By doing so, through a quantitative research design, the inquiry aimed to uncover the latent dimensions that meaningfully resonate with Filipino Gen Z pre-service science teachers. This empirical recalibration not only addressed the limitations of the original developers' seminal work but also concretised the development of a localised, generationally sensitive framework for would-be professional science teachers in a developing nation situated in the Global South. As the Philippines faces enduring educational challenges pronounced by stark regional inequalities, an under-resourced and corrupt public education system, and consistently dismal performance in international assessment metrics, such as the Programme for International Student Assessment (PISA) (Second Congressional Commission on Education [EDCOM II], 2024; 2025), the professional formation of sustainability-oriented science teachers becomes even more pressing. As Filipino Gen Z pre-service science teachers are poised to play a crucial role in shaping classrooms that nurture social justice, environmental stewardship, and functional scientific literacy (Camara & Adom, 2024), the centrality of appropriating their Sustainability Education Mindset (**"*SEM*"**) was not only a scholarly imperative but an inevitable requisite and developmental necessity; one that could help reposition the country's sustainable science teaching and learning landscape toward long-term resilience and equity.

In the theoretical lens, this inquiry enriched the current understanding of how generational mindset juxtaposes with a sustainability-oriented educational framework. Practically, this inquiry could inform the design and implementation of the sustainable science teacher education programmes, aligned with the mandate of SDG no. 4, which seeks to promote the congruence between quality, equity, and inclusivity. Understanding the cohort's SEM cultivates a fertile ground of insights into the future of Philippine science teaching, where the popular facet of Education for Sustainable Development (**"*ESD*"**) is no longer peripheral but central, and not just performative but actionable, in order to actualise the professional formation, instructional design acumen, and pedagogical excellence of the Filipino novice science teachers.

In light of the foregoing contentions, this quantitative inquiry sought to answer the following Research Questions: (1) what is the performance profile of the respondents in the SES by Çam-Tosun and Söğüt (2024)? (2) what are the factor dimensions of SE that make sense among the respondents through EFA? and (3) what is the performance profile of the respondents in the newly evolved factor dimensions of SEM?

THEORETICAL FRAMING

This quantitative inquiry was grounded in the underpinnings of Weick's (1995) Sensemaking Theory (***"ST"***), which explains how individuals construct meaning from complex and, at times, unprocessed experiences. Applied to the context of SE, a domain construed as utterly new to them due to their nature as budding professional science teachers, this conceptual lens helped unpack how Filipino Gen Z pre-service science teachers internalise the facets of sustainability as framed within the field of education amid shifting global and local challenges. In the Philippine setting, where resource disparities, curricular inconsistencies, and uneven exposure to sustainability-oriented pedagogies remain persistent features of the educational landscape (EDCOM II, 2025; 2024), ST provided a suitable framework for examining how these would-be teachers navigate ambiguity and assign relevance to sustainability principles. Such disparities frequently position learners and future teachers in environments marked by fragmented implementation of national mandates, variable access to laboratory equipment, a chronic mismatch between policy rhetoric and classroom realities, and differential opportunities to encounter sustainability discourses beyond textbook definitions. These conditions compel Filipino pre-service science teachers to rely on contextual cues and experiential fragments as they construct meaning, which is precisely the process that ST captures. Their SEM was therefore not regarded as static, but as a dynamic orientation shaped by their developing cognitive processes and contextual experiences across both well-resourced and underserved learning environments. Given their unique generational traits, the ways in which they made sense of SE carried preliminary yet meaningful implications for their future role as science teachers. To surface the latent structures that shape their SEM, the study employed an EFA, aligning with ST's emphasis on emergent patterns of understanding, which facilitated a deeper examination of the unarticulated factor dimensions guiding their educational stance toward sustainability.

METHODS AND MATERIALS

Research Design

This quantitative inquiry utilised both descriptive and exploratory designs to systematically examine the underlying SEM among the Filipino Gen Z pre-service science teachers. Descriptive statistical procedures were applied to characterise the demographic attributes and baseline performance profile in the SES and the newly evolved factor dimensions of SEM. As the study primarily aimed to identify the latent factor dimensions of the respondents' SEM, EFA was employed. While EFA does not test a specific hypothesis, it was construed as an inferential technique used to uncover the dimensional structure of the variables, especially when theoretical assumptions were limited. The use of EFA in this context was justified by the need to empirically determine the core components that define SEM as perceived by a generational and disciplinary cohort.

Research Respondents and Locales

A total of 141 Filipino Gen Z pre-service science teachers participated in this inquiry. In the context of EFA, the adequacy of sample size is critical for producing valid and stable factor solutions. Gorsuch (1983) recommended a minimum of five (5) respondents

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per item with a baseline total of at least 100 respondents, a position similarly advanced by Costello and Osborne (2005), who likewise promoted a 5:1 ratio and larger sample sizes for greater stability. The SES (Çam-Tosun & Söğüt, 2024) utilised in this study comprises 19 items, which would require at least 95 respondents to satisfy the conventional threshold. The inclusion of 141 qualified respondents exceeded this benchmark, thereby reinforcing the statistical power and reliability of the findings.

The respondents were selected through purposive sampling based on the following inclusion criteria, to wit: (a) natural-born Filipino citizen, (b) born between 1997 and 2012, qualifying them as members of the Gen Z, (c) currently enrolled in the Bachelor of Secondary Education (BSEd) major in Science programme at a Philippine Commission on Higher Education (CHEd)-recognised private Teacher Education Institution, and (d) demonstrate actual experience in Field Study sessions or teaching practicum involving science teaching in Levels 2 to 4 of their study.

The data collection was conducted in Region IV-A: CALABARZON and the National Capital Region (NCR), selected deliberately due to their strategic significance in representing the Philippines' educational, economic, and socio-cultural diversity. CALABARZON encompasses both urban and rapidly developing provincial contexts, reflecting the dynamics of access, resources, and institutional practices in peripheral yet economically vital localities (Department of Economy, Planning, and Development [Formerly National Economic Development Authority {NEDA}], 2024), while NCR represents the national epicentre of policy implementation, institutional capacity, and educational innovation in the Philippines (Edelman, 2016). Together, these regions provide a heterogeneous sample that captures variations in school types, socioeconomic backgrounds, and community infrastructures, thereby enabling a nuanced understanding of the Filipino Gen Z pre-service science teachers' SEM. The selection of these study sites balanced practical feasibility with theoretical relevance, offering insights that, while contextually anchored, provide a reasonable approximation of trends likely to be observed in other urban yet developing Philippine milieu with comparable educational and socio-economic characteristics.

Instrumentation

The study utilised a two-part instrument designed to capture both demographic and psychometric data. The initial segment gathered background information using a structured *Robotfoto*, a biographical sketch typically used in educational research (Kelchtermans & Ballet, 2002), which consisted of checkbox items and open fields on age, sex, academic standing, and science teaching experience. The second part incorporated a standardised instrument, for which prior written consent was secured from the original developers. Specifically, the SES (Çam-Tosun & Söğüt, 2024) was adopted in this study to measure the SE orientations of the respondents; thus, no part of the instrument was developed or modified by the authors. The SES is a 19-item scale comprising four (4) theoretically informed sub-dimensions: *Quality in Education*, *Inclusiveness in Education*, *Equality in Education*, and *Democratic Education*, rated on a 5-point Likert scale ranging from Strongly Disagree to Strongly Agree. Its adoption in this inquiry was informed by the rigorous development and validation procedures undertaken by the original developers. In their scale construction, Çam-Tosun and Söğüt (2024) conducted expert review processes and a content-validity assessments to 573 respondents, consistent with methodological recommendations on robust sample sizes. The instrument developers' data exhibited normal distribution (skewness = 0.231; kurtosis = –0.303; Kolmogorov–Smirnov p = .200), and the scale demonstrated high internal reliability with a Cronbach's α of 0.92. These psychometric properties provided the basis for its suitability for use in the quantitative inquiry. Consistent with the robustness of the original validation, and coincidentally, the SES, in this study, also yielded the same strong internal consistency (Cronbach's $\alpha = 0.92$), thereby supporting its reliability when administered to Filipino Gen Z pre-service science teachers.

Data Gathering Procedure

Following the identification of eligible respondents, formal invitations were extended, accompanied by a detailed brief explaining the overarching objective and scope of the inquiry. Those who expressed willingness to participate were provided a Quick Response (QR) code that linked to a secure Google Form containing the full instrument. An Informed Consent Form was integrated at the beginning of the survey and required acknowledgment before the respondents could proceed. Ethical assurances were clearly indicated, including strict adherence to data privacy and confidentiality protocols. The respondents were allotted sufficient time to complete the instrument at their convenience. Responses were meticulously reviewed for completeness, and a full response rate was achieved. The finalised data set was organised for the statistical treatment.

Data Analysis

The IBM Statistical Package for the Social Sciences (IBM-SPSS) version 25 was utilised to perform the full suite of data analyses. Descriptive statistics were employed to establish the profile of the respondents in terms of demographic and performance profile-related metrics. The same platform facilitated the EFA to empirically uncover the latent factor dimensions of SEM among the respondents. The use of EFA in this context was congruent with the study's design and objective, particularly in capturing the underlying dimensions that define SEM among the cohort. These analyses contributed directly to answering the RQs and identifying meaningful patterns in the data.

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Ethical Considerations and Extent of Artificial Intelligence (AI) Utilization

This research was thoroughly reviewed and approved by an in-house research expert focusing on ethical study clearance from the Graduate School of Centro Escolar University - Manila under course (protocol) code PRSE350-SUM2425. Prior to data collection, Informed Consent Forms were secured from all respondents, who were fully oriented on the inquiry's main objective, procedures, data handling process, and minimal to nonexistent risks. Assurances of data privacy and confidentiality and voluntary participation were emphasised, and respondents were made aware of their right to withdraw from the study at any point without being penalised. All procedures complied with the ethical guidelines of the university and the legal mandates stipulated in the Philippine Data Privacy Act and the Belmont Report. Further, concerning AI usage, the authors received assistance from the ChatGPT-40 and Grammarly platforms in minimal grammar, syntax, and expression improvement revisions.

RESULTS AND DISCUSSION

Description of the Study Respondents

The quantitative inquiry engaged 141 Filipino Generation Z pre-service science teachers enrolled in private Teacher Education Institutions (TEIs). The distribution by age and year level revealed that the majority of respondents (52.50%) were aged 23–24 years and in their fourth year of the BSEd major in Science programme. A slightly smaller proportion (46.10%) were aged 21–22 and enrolled in the third year of the programme. Only a marginal segment (2.00%) belonged to the 19–20 age group, corresponding to the second year students. This concentration of upper-year level respondents signals that the cohort has progressed through critical academic and field-based teacher training, thereby offering insights grounded in both theoretical preparation and practical science teaching exposure. Consistent with prevailing national gender patterns in teacher education, female respondents comprised a majority (67.40%), whereas male counterparts constituted 32.60% of the sample. The geographical composition reflects a near-balanced representation, with 53.90% hailing from NCR and 46.10% from Region IV-A: CALABARZON, underscoring the study's relevance to educational contexts marked by rapid urbanization, curricular innovation, and intensified sustainability discourses.

Regarding science teaching-related exposure, respondents indicated notable diversity in their field assignments. A slight majority (53.90%) reported pre-service science teaching experience in Junior High School (Grades 7–10), followed closely by 41.10% who had facilitated learning in Senior High School (Grades 11–12). This distribution mirrors the stratified and subject-specialised nature of the Philippine basic education system, particularly in the sciences. With respect to subject areas taught, Physics emerged as the most commonly facilitated domain (53.90%), closely followed by Biological Science (46.10%) and Chemistry (39.70%). Fewer respondents had teaching exposure in Earth and Life Science (28.40%), Environmental Science (24.80%), and Integrated Science (15.60%). These figures point to a content-specific skew, where certain science domains, particularly those aligned with the Physical and Biological Sciences, are more frequently assigned in practicum contexts. Notably, the underrepresentation in sustainability-related subjects such as Environmental Science and Earth and Life Science may signal a systemic gap in the pre-service science teacher curriculum integration of sustainability competencies. This discrepancy, while reflecting institutional curricular arrangements, also opens critical conversations on how science teacher preparation programmes can expand disciplinary exposure to more fully align with the imperatives of ESD.

Exposition of the Statistical Analyses

The Research Question 1: *What is the performance profile of the respondents in the SES by Çam-Tosun and Söğüt (2024)?*

The performance profile of the Filipino Generation Z pre-service science teachers in the SES revealed meaningful patterns in their developing orientations toward education that are future-focused, equitable, and participatory. Among the four (4) measured sub-dimensions, the highest mean scores were observed in *Quality in Education* (M = 3.63, SD = 0.65) and *Democratic Education* (M = 3.63, SD = 0.63). These findings suggest that the respondents hold strong pedagogical beliefs aligned with academic excellence and collaborative, student-centred learning environments. Such priorities reflect a generational shift toward embracing educational systems that are both rigorous and dialogic in nature. Liou and Rojas (2022) argued that such principles are recognised as foundational in the discourse of sustainable development. Moreover, these scores may be attributed to their exposure to modern instructional frameworks that emphasise learner agency, dynamic assessment and evaluation, and evidence-informed practices, which are increasingly integrated into teacher education curricula across TEIs in the Philippines (EDCOM II, 2024).

Table 1

The Respondents' Performance Profile in the SES

The SES Sub-dimensions	N	Min	Max	Mean	Std Dev
Quality in Education	141	1.50	5.00	3.63	0.65
Inclusiveness in Education	141	1.20	5.00	3.31	0.84
Equality in Education	141	1.77	5.00	3.53	0.66
Democratic Education	141	1.66	5.00	3.63	0.63

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Furthermore, *Equality in Education* also received a relatively high mean (M = 3.53, SD = 0.66), signaling that respondents recognise the ethical imperative of fair treatment and resource allocation within learning systems. However, a noteworthy divergence emerges in *Inclusiveness in Education*, which yielded the lowest mean score (M = 3.31, SD = 0.84) and the widest variability among all domains. This lower average, coupled with the elevated standard deviation, suggests significant inconsistencies in how inclusivity is understood or internalised by pre-service science teachers. The finding is not unexpected. Gen Z, while characterised by digital fluency and global awareness, often struggles to translate abstract ideals of inclusion into actionable classroom practices, particularly in settings with limited exposure to diverse learner needs (Lazar et al., 2023). In the Philippine context, inclusive education remains a policy aspiration more than a consistently enacted classroom reality, especially in science education, where differentiated instruction and universal learning design are not yet robustly institutionalised (EDCOM II, 2025). This finding underscores the need for more intentional integration of diversity training, inclusive pedagogies, and authentic encounters within learner groups in pre-service science education programmes, not only to foster deeper socio-pedagogical awareness but also to ensure that the sustainability of education systems is responsive to all would-be professional science teachers.

The Research Question 2: *What are the factor dimensions of SE that make sense among the respondents through EFA?*

The EFA offered insightful stances on the SEM of Filipino Gen Z pre-service science teachers. The analysis was conducted using principal component analysis with Varimax rotation, an orthogonal rotation method selected to maximise interpretability by producing distinct, uncorrelated dimensions. Before extraction, the dataset's suitability for EFA was confirmed: the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy yielded 0.93, and Bartlett's Test of Sphericity was significant ($\chi^2 = 2157.82$, $p < 0.001$). All nineteen (19) SES items were therefore subjected to EFA.

Retention criteria followed established statistical conventions, whereby items with factor loadings or communalities below 0.40 would be excluded; in this instance, every item met the threshold and was retained. For transparency, the complete Rotated Component Matrix is presented in Table 2, and each item was evaluated across the three (3) emergent factors, with assignment determined primarily by the highest factor loading. In stark contrast, items that exhibited secondary loadings within the approximate range of 0.30–0.35 were not classified under multiple factors because these values are generally considered minimal and do not indicate meaningful cross-loading. At that magnitude, the secondary loading does not outweigh an item's substantially stronger primary loading nor its theoretical alignment, allowing confident assignment to the most conceptually appropriate factor. By systematically aligning each item with its strongest loading and considering theoretical relevance in instances of cross-loading, the analysis established a transparent audit trail that evidences the conceptual rigour of the three-factor SEM structure.

For illustrative purposes, items reflecting introspective and retrospective concerns about equality and access, for example, "*There are no differences among public schools in terms of the opportunities provided to the individuals in my country*" (loading = 0.82 on Factor 1) and "*There are no regional differences in the access to schools among students in my country*" (0.82 on Factor 1), were grouped under *Reflective Thinking*. Additionally, items denoting structural and policy responsiveness, such as "*The right to education is legally guaranteed to the individuals in my country*" (0.75 on Factor 2) and "*There are effective national policies on access to education in my country*" (0.73 on Factor 2), were assigned to *Systems Thinking*. Moreover, statements emphasising forward-looking, participatory and adaptive capacities, including "*Education is provided to the individuals with an approach respecting their cultural differences in my country*" (0.84 on Factor 3) and "*The education system in my country provides the individuals with problem-solving abilities*" (0.69 on Factor 3), were categorised under *Futures Thinking*. Table 3 summarises the three (3) factor dimensions in order of decreasing explained variance; each factor attained an eigenvalue greater than one (1) and demonstrated strong internal consistency (Cronbach's α = 0.85–0.92).

Table 2

The Rotated Component Matrix

SES Items	Component		
	1	2	3
There are no differences among public schools in terms of the opportunities provided to the individuals in my country.	**.82**	.31	.16
There are no regional differences in the access to schools among students in my country.	**.82**	.28	.20
There are no individuals who cannot go to school due to financial inadequacies in my country.	**.77**	.34	.24
There are no differences between the schools located in various settlements (urban vs rural areas in my country).	**.76**	.30	.24
Employment of the educated individuals is supported.	**.63**	.38	.24
There is no difference between private and public schools in terms of the opportunities provided to the individuals in my country.	**.57**	.28	.22

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SES Items	Component		
	1	2	3
The right to education is legally guaranteed to the individuals in my country.	.16	**.75**	.13
There are effective national policies on access to education in my country.	.27	**.73**	.27
Individuals have lifelong learning opportunities in my country.	.27	**.70**	.33
Free education is provided at all levels to the individuals in my country.	.31	**.70**	.05
There are effective national policies on equality in education in my country.	.30	**.61**	.16
The education system can respond to national needs.	.34	**.53**	.15
Compulsory education is provided at all levels to the individuals in my country.	.34	**.50**	.27
The rate of schooling is high in my country.	.35	**.44**	.24
Education is provided to the individuals with an approach respecting their cultural differences in my country.	.06	.25	**.84**
Individuals are not discriminated against due to their language, religion, ethnicity, gender, etc. during their education in my country.	.26	.12	**.75**
The education system in my country provides the individuals with problem-solving abilities.	.35	.17	**.69**
There is a democratic environment in the educational institutions.	.33	.32	**.65**
The education system can respond to international needs.	.32	.21	**.47**

Table 3

The Exploratory Factor Analysis of the SES

Sustainability Education Mindset (SEM) Factor Dimensions and Items	Factor Loading	Eigenvalue	Variance (%)	Reliability Coefficient
Factor Dimension 1: *Reflective Thinking*: Sustainability Education as Looking Back		3.22	25.48	0.92
There are no differences among public schools in terms of the opportunities provided to the individuals in my country.	0.82			

Sustainability Education Mindset (SEM) Factor Dimensions and Items	Factor Loading	Eigenvalue	Variance (%)	Reliability Coefficient
There are no regional differences in the access to schools among students in my country.	0.82			
There are no individuals who cannot go to school due to financial inadequacies in my country.	0.77			
There are no differences between the schools located in various settlements (urban vs. rural areas) in my country.	0.75			
Employment of the educated individuals is supported.	0.63			
There is no difference between private and public schools in terms of the opportunities provided to the individuals in my country.	0.57			
Factor Dimension 2: *Systems Thinking*: Sustainability Education as Looking Within		3.16	20.41	0.89
The right to education is legally guaranteed to the individuals in my country	0.75			
There are effective national policies on ACCESS to education in my country.	0.73			
Individuals have lifelong learning opportunities in my country.	0.70			
Free education is provided at all levels to the individuals in my country.	0.69			
There are effective national policies on EQUALITY in education in my country.	0.61			
The education system can respond to national needs.	0.53			
Compulsory education is provided at all levels to the individuals in my country.	0.50			
The rate of schooling is high in my country.	0.44			
Factor Dimension 3: *Futures Thinking*: Sustainability Education as Looking Forward		2.38	19.68	0.85
Education is provided to the individuals with an approach respecting their cultural differences in my country.	0.84			

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Sustainability Education Mindset (SEM) Factor Dimensions and Items	Factor Loading	Eigenvalue	Variance (%)	Reliability Coefficient
Individuals are not discriminated against due to their language, religion, ethnicity, gender, etc. during their education in my country.	0.75			
The education system in my country provides the individuals with problem solving abilities.	0.69			
There is a democratic environment in the educational institutions.	0.65			
The education system can respond to international needs.	0.47			
Total Explained Variance			65.57	

Notes: Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.93 (93%);
Bartlett's Test of Sphericity = 2157.82 ($p < .001$)

Reflective Thinking: Sustainability Education as Looking Back

The first emergent factor dimension centred on the cognitive orientation among Filipino Gen Z pre-service science teachers that foregrounds the role of introspection and critical retrospection in understanding SE. Within this mindset, sustainability is not framed purely as a vision of the future but as a necessary process of confronting historical inequalities, institutional failures, and personal and educational experiences. These future science teachers approach sustainability as a form of social remembering. It is through this remembering that they evaluate current systems and imagine improved futures for science education.

This depiction aligns meaningfully with the structure of the SES developed by Çam-Tosun and Söğüt (2024), which comprises four (4) interrelated sub-dimensions: *Quality in Education, Inclusiveness in Education, Equality in Education*, and *Democratic Education*. The components that contributed most substantially to this factor dimension originated primarily from *Inclusiveness in Education*. Comparatively fewer were sourced from *Democratic Education* and *Quality in Education*. This trend underscores the centrality of inclusion in the SEM of this cohort. Filipino Gen Z learners, raised in an era defined by interconnectedness, digital fluency, and heightened awareness of systemic inequalities, are acutely attuned to the exclusions that often go unnoticed in traditional educational discourse (Obmerga & Yambao, 2025). For science education in particular, which remains disproportionately affected by resource inequities, this group's sensitivity to inclusion is grounded in their dynamic experience and their yearning for a fair and equitable academic future (Hope, 2016).

The specific statements that define this factor dimension, ranked by their respective explanatory power in the EFA output, articulate the reflective concerns of these pre-service teachers. Each response highlights a perspective that ignores the material disparities in Philippine education. Their reflections are discussed below in order of their factor loadings, from highest to lowest, to capture the nuanced evolution of the mindset embedded in this factor. One of the strongest responses came in reaction to the statement, "*There are no differences among public schools in terms of the opportunities provided to the individuals in my country*." Respondents responded critically to this proposition, indicating that such a claim does not reflect the educational landscape they have experienced. EDCOM II (2024) expounded that in many parts of the Philippines, public schools differ widely in terms of resources, teacher competence, infrastructure, and support systems. Urban schools often enjoy preferential access to technology, qualified science teachers, and supplemental programs. Meanwhile, rural schools may struggle with chronic shortages and inadequate facilities. For science education, these disparities are especially glaring. The uneven distribution of laboratory resources, updated curricula, and experiential learning opportunities directly impairs scientific literacy (Obmerga, 2025). Gen Z pre-service teachers reflect on these experiences not with indifference but with analytical urgency. Their SEM confronts the false assumption of parity, advocating instead for targeted interventions that acknowledge and address existing gaps.

Additionally, a similar insight is evident in the statement, "*There are no regional differences in the access to schools among students in my country*." The respondents overwhelmingly found this assertion to be inconsistent with reality. The geographical configuration of the Philippines, consisting of thousands of islands, inherently creates access disparities. Symaco (2013) explicated that Filipino students in remote or mountainous areas may have to travel long distances to attend school, often under difficult conditions. Science education, which demands consistency, practical engagement, and teacher expertise, suffers disproportionately under these circumstances (Macias et al., 2022). For Gen Z pre-service teachers, who value equity and access as core dimensions of ESD, recognising these regional imbalances is an essential part of their reflective process. Their SEM suggests a holistic understanding of education that transcends curriculum content, focusing instead on the systems that enable or obstruct science learning.

Moreover, included in this factor dimension is the statement, "*There are no individuals who cannot go to school due to financial inadequacies in my country*." This response revealed a grounded understanding of the persistent economic barriers that limit educational participation. Despite constitutional provisions and Philippine public education reforms, hidden costs, such as school supplies, transportation, and miscellaneous fees, continue to exclude marginalised learners (EDCOM II, 2025). The implications are even more severe in science education, where access to materials and enrichment activities is crucial. Filipino Gen Z pre-service teachers, many of whom have

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experienced or witnessed economic hardship, reject narratives that erase poverty's role in educational attainment. Their reflective thinking does not simply acknowledge the problem; hence it links systemic economic inequality with the broader sustainability agenda, positioning education as both a right and a lever for social mobility. Moreover, the statement, "*There are no differences between the schools located in various settlements (urban vs. rural areas) in my country*," elicited a parallel critical response. The respondents became concerned with the persistent gap between urban and rural educational contexts, particularly in terms of teacher quality, access to science laboratories, and exposure to advanced pedagogical strategies. In rural areas of the Philippines, the lack of updated instructional materials and underqualified science educators has direct implications for the development of scientific competencies (San Luis & Villafranca, 2022), a challenge that mirrors conditions reported in other developing contexts such as India (Bansal et al., 2013), Vietnam (Lo, 2022), and South Africa (Chuene & Teane, 2024), where resource limitations similarly shape pre-service teachers' readiness for sustainability-oriented instruction. The respondents' quantified views suggest that SE cannot proceed without addressing the structural imbalances that shape students' learning environments, and their mindset is attuned to the ethical responsibility of correcting such inequities.

Further, regarding the statement, "*Employment of the educated individuals is supported*," respondents fielded doubts about the practical outcomes of educational attainment. They are aware that while many educators complete their degrees, employment opportunities, particularly in specialised science-related fields, remain scarce or misaligned with their qualifications (National Economic and Development Authority, 2021). This perceived disconnect between education and labour market outcomes undermines the sustainability of the education system itself. For Gen Z pre-service science teachers, the ability to translate learning into meaningful employment is integral to the concept of SE. The inclusion of this statement in this factor indicates a demand for a prudent overhaul that ensures education leads to equitable participation in economic and civic life.

Finally, the statement, "*There is no difference between private and public schools in terms of the opportunities provided to the individuals in my country*," received the lowest factor loading within this dimension but remains a meaningful indicator of reflective engagement. The respondents treated this statement based on visible stratifications in resources, curricular flexibility, teacher training, and student support systems. In the realm of education, private institutions often have greater autonomy and investment in laboratories, research exposure, and global collaborations (Casani et al., 2014). Public schools, especially in developing nations, are often limited by rigid bureaucratic structures and funding constraints (EDCOM II, 2024). For Gen Z pre-service teachers, such constraints are not simply institutional differences. The respondents tagged it as ethical breaches that hinder equitable learning.

True to the sensemaking nature of the inquiry, the reflective dimension of the Filipino Gen Z pre-service science teachers' SEM underscores critical awareness of inequities and inequalities in Philippine education, highlighting persistent disparities across geographic, economic, and institutional contexts. These insights suggest actionable strategies for teacher education programmes, particularly in preparing future Filipino science educators to navigate and address challenges. For instance, curriculum design can integrate case-based modules that simulate urban–rural resource discrepancies, financial barriers, and private–public school contrasts, enabling trainees to develop diagnostic and adaptive competencies before entering classrooms. Additionally, pedagogical training may include reflective exercises, problem-based learning, and community-embedded projects that cultivate sensitivity to inequities, promote equity-driven instructional planning, and foster innovative approaches to SE. Moreover, embedding discussions on the alignment between educational attainment and labour market outcomes can sensitise Filipino pre-service science teachers to the socio-economic dimensions of sustainability, informing strategies that link learning experiences to meaningful civic and professional engagement. Collectively, these interventions can operationalise the reflective component of SEM revealed in this study, ensuring that future science educators are equipped not only with content knowledge but with the ethical and reflective capacities necessary for fostering inclusive and sustainable science learning environments.

Systems Thinking: Sustainability Education as Looking Within

The second emergent factor dimension encapsulated a mindset grounded in procedural coherence, interconnectedness, and systemic appraisal of educational structures. The Filipino Gen Z pre-service science teachers appear to conceptualise SE as a matter of structural logic and institutional scrutiny. This orientation reflects a deliberate cognitive process wherein sustainability is perceived not merely through external interventions, but as an organic reconfiguration of education systems that are evaluated for consistency, responsiveness, and alignment with long-term social needs.

In reference to the SES developed by Çam-Tosun and Söğüt (2024), this newly evolved component of the SEM draws exclusively from two (2) sub-dimensions: *Equality in Education* and *Quality in Education*. Notably, elements from *Inclusiveness in Education* and *Democratic Education* were absent in this factor. The majority of the responses clustered around *Equality in Education*, with only one originating from *Quality in Education*. This distribution revealed that the respondents are attuned to the systemic guarantees and institutional obligations that promote equitable access and educational quality. Their systems-oriented lens reflects a consciousness shaped by both hyperconnectivity and skepticism toward performative reforms. It is also influenced by the realities of science education, which demands both structural integrity and equitable participation (Rodriguez

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& Morrison, 2019). This internal evaluation of the educational ecosystem becomes the foundation from which sustainability is understood and critiqued.

The statements comprising this factor dimension are presented below, ordered by their descending explained variance from the EFA results. Each entry is presented with analytical sensitivity to the construct of systems thinking, further elucidating how the respondents rationalise sustainability from within the climate of Philippine science education. First, the statement, "*The right to education is legally guaranteed to the individuals in my country*," resonates strongly within this dimension. Its inclusion suggests that respondents consider the codification of educational rights as a foundational indicator of systemic sustainability. Science education, in particular, cannot be effectively delivered without a legal framework that mandates universal participation (Tate, 2001). Systems thinking, in this context, requires not only policy rhetoric but enforceable actions that translate into lived access. Respondents appear to recognise that SEM includes notions of structures that affirm and protect the fundamental right to learn.

Following closely is the statement, "*There are effective national policies on ACCESS to education in my country*." This reflects an evaluative stance on whether access is not only declared but systemically enabled through Philippine policy mechanisms. Within science education, access extends beyond physical entry into classrooms to include equitable access to laboratories, digital tools, and scientific discourse (Obmerga, 2025). The presence of this statement within the factor underscores how systems thinking involves the scrutiny of policy implementation and not just its formal existence. Likewise, the statement, "*Individuals have lifelong learning opportunities in my country*," introduces a temporal dimension to the systemic view of sustainability. Lifelong learning is a key indicator of a dynamic, forward-looking education system. For science education to be sustainable, it must be responsive to the changing knowledge landscape and provide mechanisms for continual upskilling (Marangio et al., 2024). Respondents likely situated this notion within the broader systemic responsibility to sustain intellectual growth beyond formal schooling.

Additionally, the entry, "*Free education is provided at all levels to the individuals in my country*," reflects a critical metric of systemic equity. In a nation where financial barriers often limit educational attainment (EDCOM II, 2024), particularly in science and technology disciplines, the promise of free education represents a structural commitment to social mobility. Respondents appear to regard this as a key marker of sustainability, suggesting that a just system must be capable of absorbing costs to ensure that opportunity is not limited by socioeconomic status. In a similar vein, the statement, "*There are effective national policies on EQUALITY in education in my country*," reinforces the systemic orientation of this factor. It aligns with a mindset that sees sustainability not as an abstract goal, but as a measure of whether systems are operating equitably across regions, sectors, and demographics (Clark, 2015). Dagnino (2012) typified that science education, which has historically mirrored social inequalities, especially in marginalised communities, can only be sustainable when underpinned by policies that consciously rectify such disparities.

Moreover, the inclusion of the statement, "*The education system can respond to national needs*," suggests that respondents evaluate sustainability through the lens of systemic adaptability. A sustainable education system must be calibrated to serve both current and future societal demands, especially in science education, where innovation and national development are tightly linked (EDCOM II, 2025). This response reveals a demand for functional responsiveness, where institutional structures are evaluated for their capacity to contribute meaningfully to national progress. Further, the item, "*Compulsory education is provided at all levels to the individuals in my country*," signals the perceived role of enforcement mechanisms in system sustainability. While the aspiration of universal education is often shared, its actualisation requires compulsory mandates that ensure minimum participation. In an educational systems thinking paradigm, stakeholder participation is not merely about regulation but about ensuring foundational school access and equity, particularly in early science literacy and engagement (Varelas et al., 2015).

Finally, the statement, "*The rate of schooling is high in my country*," reflects a surface-level indicator that, when interpreted through systems thinking, becomes a diagnostic entry point for deeper scrutiny. Although school retention rates often signal educational progress, especially in the Philippine locality (EDCOM II, 2024), respondents appear to interrogate this metric beyond its numerical value, much like findings from educational studies in countries such as Malaysia (Ahmad et al., 2019) and Turkey (Ulum & Küçükaydın, 2024), where science learners' intent for science study and career aspiration, respectively, does not necessarily translate into robust science learning outcome attainment due to the quality of their academic stint and school experiences. Their worldview suggests that what matters is not only participation but also whether increased access corresponds with high-quality science instruction. Nachbauer and Kyriakides (2020) posited that it is crucial for educators to determine if there is an equitable distribution of educational opportunities as it can spell a positive difference on the attainment of learners' current and future competencies.

Grounded on this systemic orientation as an avenue for sensemaking, pre-service teacher education programmes must intentionally cultivate the capacity of budding educators to critically evaluate educational structures, policies, and institutional practices that shape learning outcomes. Filipino novice teachers could benefit from structured opportunities to interrogate inequities in resource distribution, access to laboratories, teacher competence, and policy implementation, particularly in science education. Curricular enhancements could include practicum placements in both under-resourced

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(public) and high-performing (private) schools, policy analysis exercises that link legal frameworks and equality mandates to classroom realities, and reflective modules that encourage critical synthesis of institutional obligations with pedagogical practice. By integrating problem-based simulations and collaborative projects that mirror systemic challenges, prospective educators can design and advocate for interventions that promote inclusive, high-quality science learning experiences. Such approaches ensure that such emerging educators are not only aware of systemic barriers but are equipped to translate SEM insights into actionable competencies, advancing sustainability, equity, and educational excellence, ultimately positioning Filipino Gen Z pre-service science teachers as agents of transformative, contextually responsive educational change in the Philippine context.

Futures Thinking: Sustainability Education as Looking Forward

The third emergent factor dimension embodied the forward-oriented outlook of Filipino Gen Z pre-service science teachers. This mindset is deeply anchored in their vision of an education system that anticipates and actively prepares for future societal, cultural, and scientific challenges. It also reflects a generational inclination to evaluate science education not just for its current outcomes, but for its capacity to adapt and evolve for long-term sustainability. The notion of looking forward, in their purview, emerges not as a passive hope, but as a strategic engagement with what education and science education must become.

Within the framework of the SES developed by Çam-Tosun and Söğüt (2024), this factor dimension draws primarily from the sub-dimensions of *Democratic Education* and *Quality in Education*. Only one statement stems from *Inclusiveness in Education*, while *Equality in Education* is entirely absent. The balanced representation of *Democratic Education* and *Quality in Education* facets in this factor underscores how the respondents conceptualise the future of education as contingent on openness, participation, and excellence. Raised in an era of global crises, digital revolutions, and amplified discourse on social justice, these respondents are predisposed to scrutinise how educational systems uphold democratic ideals while cultivating competencies that are relevant to a rapidly changing world (Obmerga & Yambao, 2025). This orientation is particularly salient in science education, where ethical inquiry, cross-cultural engagement, and problem-solving lie at the heart of meaningful learning (Zidny et al., 2020).

The following statements, arranged according to their decreasing explained variance, comprise the dimension of *Futures Thinking*. Each statement contributes to the conceptual scaffold through which respondents appraise SE as a proactive endeavour. The first statement, "*The education is provided to the individuals with an approach respecting* *their cultural differences in my country*," signals a critical awareness of multicultural responsiveness as a marker of sustainable futures. Respondents appear to regard cultural respect not simply as an ethical stance, but as a functional imperative in an increasingly diverse and interconnected world. In science education, where universal laws intersect with indigenous knowledge systems, honouring cultural diversity fosters inclusivity, creativity, and contextual relevance (Handayani et al., 2018). This stance aligns closely with Gen Z's global exposure and their expectation that education must be sensitive to diverse identities and histories (Mahapatra et al., 2022).

Additionally, the item, "*Individuals are not discriminated against due to their language, religion, ethnicity, gender, etc. during their education in my country*," amplifies the notion of sustainability as inherently tied to social justice. This perspective aligns with the ideals of democracy, where equity of treatment underpins meaningful participation. Munalim (2019) averred that in the Filipino context, where socioeconomic and ethno-linguistic disparities are deeply embedded in the education system, the absence of discrimination is not merely aspirational but essential for any future-ready education. In Philippine science classrooms, where historically marginalised groups often remain underrepresented, creating a non-discriminatory learning environment is critical to cultivating a sustainable scientific community (EDCOM II, 2025).

Moreover, the statement, "*The education system in my country provides the individuals with problem solving abilities*," positions education as a driver of adaptive skill formation. Problem-solving is a core competency in both sustainability and science education (Alkair et al., 2023), and comparative research shows how developed countries, such as Singapore and Finland, strengthen this competency through robust teacher preparation systems, coherent national curricula, and consistent investments in instructional quality. Singapore cultivates problem-solving through inquiry-based science pathways and rigorous professional learning systems for teachers (Rose, 2025), while Finland embeds multi-phenomenon competencies and real-world problem contexts across subjects through highly autonomous, research-trained educators (Schaffar & Wolff, 2024). These approaches contrast with the Philippine setting, where systemic constraints such as uneven teacher training quality and resource disparities often limit the depth of problem-solving instruction (Obmerga, 2025). Against this backdrop, the respondents recognised that their future praxis requires equipping science learners with the cognitive flexibility and resilience needed to navigate uncertainty. This aligns with their generational disposition toward innovation and their lived experience in a world shaped by crises that require systemic solutions (Azman et al., 2021).

Further, the statement, "*There is a democratic environment in the educational institutions*," reinforces the importance of participatory structures as a foundational element to SE. Democratic environments foster dialogic learning, shared responsibility, and collective action (Ferguson-Patrick, 2020). All of which are crucial in the context of science education, where debate, modes of inquiry, and ethical reflexivity are integral to practice (Mamutse, 2024). Despite their concentration on the sciences, the respondents' greater regard for democracy in schools suggests a recognition that the future of education must be built on institutional cultures that encourage voice, agency, and critical engagement, rather than passive compliance.

Finally, the statement, "*The education system can respond to international needs*," highlights the global orientation of respondents. Sustainability in education is understood here as the ability to align with and contribute to transnational challenges, such as climate change, technological disruption, and public health (Hays & Reinders, 2020). Valladares (2021) noted that in science education, the element of responsiveness among its primary agents is critical as scientific literacy must transcend national boundaries to address global concerns. The respondents appear to evaluate sustainability not in isolation, but in relation to how education prepares learners to act on the world stage.

Building on the forward-looking orientation of the respondents, pre-service teacher education programmes must strategically cultivate the capacity to anticipate and respond to emerging societal, scientific, and educational challenges. In line with the sensemaking nature of these findings, prospective educators could benefit from visionary yet structured opportunities to develop progressive problem-solving skills, foster anticipatory democratic engagement, and immerse themselves to cultural, linguistic, and socio-economic diversity as central elements of SE. Curricular innovations in teacher training could integrate scenario-based learning that situates science teaching within complex, real-world problems, comparative analyses of exemplary systems, especially the ones actively using the Next Generation Science Standards (NGSS), and innovative modules linking democratic participation to classroom practice. Practicum placements in diverse school settings could provide direct exposure to inclusive and participatory teaching contexts, while collaborative projects and simulations could promote adaptive thinking and futuristic decision-making. By embedding these approaches, Philippine teacher education programmes can translate the Futures Thinking insights into actionable competencies, enabling Filipino Gen Z pre-service science teachers to design and implement pedagogical strategies that advance equity, responsiveness, and global relevance, positioning them as proactive agents in shaping a sustainable, future-ready science education landscape.

The Research Question 3: *What is the performance profile of the respondents in the newly evolved factor dimensions of SEM?*

Table 4

The Respondents' Performance Profile in the SEM

The SEM Sub-dimensions	N	Min	Max	Mean	Std Dev
Reflective Thinking	141	1.00	5.00	3.27	1.04
Systems Thinking	141	1.00	5.00	3.63	0.80
Futures Thinking	141	1.00	5.00	3.72	0.74

The performance profile of the respondents across the newly evolved SEM dimensions revealed a differentiated yet promising pattern of their cognitive orientation toward sustainability in science education. *Futures Thinking* emerged as the highest-scoring dimension (M = 3.72, SD = 0.74), suggesting that Filipino Gen Z pre-service science teachers demonstrate an emerging disposition toward anticipating long-term educational and societal challenges and interventions. This result may indicate their capacity to envision transformative possibilities in science teaching that align with global sustainability agenda (Obmerga & Yambao, 2025). Closely following is *Systems Thinking* (M = 3.63, SD = 0.80), reflecting a growing ability to recognise interconnections among environmental, social, and academic systems. York and collaborators (2019) argued that system recognition and intervention are competencies crucial to navigating the complexities of real-world scientific issues. Meanwhile, *Reflective Thinking* received the lowest mean (M = 3.27, SD = 1.04), with a comparatively wide spread of responses. This implies that while some respondents exhibit strong introspective-cognitive engagement, others remain underdeveloped in this area. The high standard deviation further indicates a notable variation in internalised self-awareness and critical reflection among the respondents. Self-awareness is tagged as a foundational element for the ethical and pedagogical sensitivity required of sustainability-oriented science educators (Birdsall, 2014). The SEM performance data affirm that while the certain cognitive scaffoldings for SE are tagged as promising among Gen Z science teacher candidates, there remain nuanced areas for developmental support, particularly in cultivating more consistent habits of reflective inquiry and value-based decision-making.

Applying a comparative lens with the original SES by Çam-Tosun and Söğüt (2024), the SEM results demonstrate both conceptual alignment and subtle divergence. The high scores in *Futures Thinking* (M = 3.72) and *Systems Thinking* (M = 3.63) parallel the original SES results, where *Quality in Education* (M = 3.63) and *Democratic Education* (M = 3.63) also registered strong performance, suggesting a generational leaning toward forward-thinking and participatory educational ideals. This alignment implies a shared cognitive schema underlying both traditional and evolved conceptualizations of SE. However, a

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divergence becomes apparent in the SEM sub-dimension of *Reflective Thinking* (M = 3.27, SD = 1.04), which mirrors the relatively low performance in *Inclusiveness in Education* (M = 3.31, SD = 0.84) from the SES. Both sub-dimensions reflect internal-facing dispositions that are evidently less developed among respondents, such as empathy, self-examination, and moral imagination. These stances illuminate the layered nature of SEM and underscore the importance of integrating both structural and introspective competencies in the preparation of future professional science educators.

CONCLUSION

The quantitative study purported to understand the SEM of Filipino Generation Z pre-service science teachers through the lens of EFA. Anchored in the 19-item SES by Çam-Tosun and Söğüt (2024), the inquiry sought not merely to measure existing sub-components of the scale but to emerge cognitive dimensions that are sensitive to SE sensibilities of the respondents. Through rigorous statistical processing and analysis, three (3) factor dimensions were identified, offering a more nuanced framework for understanding the cognitive orientations that shape the SEM of this distinct cohort. The study's theoretical contributions, practical implications, limitations, and future research directions are discussed below:

Theoretical Contributions

This research makes three (3) significant theoretical contributions. First, while previous inquiries have explored the perspectives of Filipino Gen Z science teachers, the majority have focused on in-service educators and examined distinct phenomena such as laboratory teaching praxis (Obmerga, 2025) and informal professional learning (Obmerga & Yambao, 2025). This study is among the earliest probes to investigate the SE schema of pre-service science teachers, thereby foregrounding a unique population at a critical juncture in their professional formation. Second, with the integration of the SDGs into educational knowledge production, there has been a notable rise in SE-related research. Yet, within developing contexts like the Philippines, such efforts have largely concentrated on the general education milieu (Jintalan & Litao, 2024). This work emerges as one of the foundational inquiries that specifically interrogates SE within the domain of science education, contributing to a growing yet still limited body of literature that localises the sustainability agenda in the discipline. Third, the EFA segment of this study introduced three (3) factor dimensions as meaningful markers of the SEM among Filipino Gen Z pre-service science teachers.

Practical Implications

Inductively emerging from the sensemaking perspectives of Filipino Gen Z pre-service science teachers on their SEM, the practical implications of this inquiry underscore the imperative for teacher education programmes to cultivate reflective, systemic, and forward-looking competencies that operationalise SE. By engaging emerging science teachers in case-based modules, problem-based learning, and community-embedded projects, professional science teacher formation in the Philippines can immerse future science educators to structural inequities (including geographic, economic, and institutional disparities), while promoting diagnostic, adaptive, and equity-driven pedagogical skills. Integrating teaching practicum placements across under-resourced and high-performing schools, alongside policy analysis exercises and reflective modules, enables prospective science teachers to interrogate educational structures, legal mandates, and institutional obligations, translating systemic awareness into classroom practice. Complementarily, scenario-based simulations, collaborative projects, and comparative analyses of exemplary national and international educational systems foster anticipatory problem-solving, ethical decision-making, and culturally responsive instruction, equipping trainees to anticipate societal and scientific challenges. Collectively, these curricular and experiential strategies could help transform the SEM dimensions of *Reflective*, *Systems*, and *Futures Thinking* into actionable competencies, positioning Filipino Gen Z pre-service science teachers as proactive agents capable of designing, advocating for, and implementing inclusive, high-quality, and future-ready science education that advances sustainability, equity, and global relevance.

Limitations

This study acknowledges several limitations inherent in its design and methodological choices. First, while EFA is a robust tool for uncovering latent structures, it is inherently sample-dependent, which limits the generalisability of the findings beyond the present cohort. To mitigate this, the study employed a sample size that exceeded the minimum thresholds recommended by Gorsuch (1983) and Costello and Osborne (2005), thereby enhancing factor stability and interpretive reliability. Nonetheless, EFA does not provide confirmatory evidence of the factor structure (See Future Research Direction). Second, the study utilised purposive sampling, focusing exclusively on Filipino Gen Z pre-service science teachers from CALABARZON and NCR, which may limit the representativeness of the findings across other Philippine regions or teacher cohorts with different socio-cultural or institutional contexts. Third, respondents' limited disciplinary exposure to a core SDG driver and avenue, the Environmental Science, as revealed in the inquiry's demographic exposition, may have influenced their perceptions, potentially constraining the depth of sustainability-related sensemaking captured by the survey.

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Finally, as with many self-report instruments, cultural and contextual factors could introduce measurement biases, particularly in the interpretation of items derived from scales developed in other educational contexts (Çam-Tosun & Söğüt, 2024).

Future Research Directions

Scholars are encouraged to validate the factor dimensions through Confirmatory Factor Analysis (CFA), which would test the robustness and generalisability of the dimensions across diverse populations and educational settings. Furthermore, qualitative research designs, such as phenomenology and autoethnography, can yield rich and thick complementary insights into the lived experiences and evolving worldviews of Filipino pre-service and in-service science teachers toward SE.

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ABOUT THE AUTHOR

Dr. MARWIN E. OBMERGA is a licensed professional science teacher and registered nurse under the Professional Regulation Commission (PRC) of the Philippines; a licensed school principal under the Illinois State Board of Education (ISBE), Chicago, IL, USA; a recognised author/writer and a subject matter expert under the National Book Development Board (NBDB) – Philippines; and an associate member of Division I: Governmental, Educational, and International Policies of the National Research Council of the Philippines (NRCP). He earned his Doctor of Philosophy in Education, major in Educational Management and Leadership (summa cum laude), from the University of Santo Tomas, Manila. Currently, he serves as a Professorial Lecturer VII at the Undergraduate Studies (UGS) & Graduate Studies and Transnational Education (GSTE) Departments of the Far Eastern University, Manila – Institute of Education. As a dynamic and award-winning early career scholar, he has graced the pages of several Web of Science (Clarivate) and Scopus-indexed international journals, primarily in Quartiles 1 and 2-ranked publications; and was hailed as one of the winners of the 4th Loretta Makasiar Sicat (LMS) Prize for the Social Sciences, a nationwide competition organised by the Philippine Social Science Council (PSSC) to recognise exceptional Filipino social science researchers. Apart from being an active Peer Reviewer for prestigious scholarly journals based in the United States, Europe, and Asia; being a sought-after resource person on graduate research, high-impact publication, pedagogy, and learning design across the Philippines; and serving as an Administration Consultant to his family-owned preschool in Sacramento, CA, USA, he is also a candidate for a second doctorate degree in Science Education at Centro Escolar University, Manila.

Dr. DENNIS G. CABALLES is a cum laude graduate of Philippine Normal University with the degree of Bachelor of Secondary Education major in General Science and an alumnus of De La Salle University Manila from master's up to doctorate level with the degree Master of Arts in Teaching Major in General Science and Doctor of Philosophy in Science Education major in Biology, respectively. At present, he is the Assistant Vice President for Academic Affairs of the City University of Pasay.