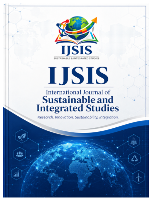

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# Enhancing Sustainability Competence and Self-Efficacy of Junior High School Teachers Through a Holistic Teaching Intervention

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**Abstract**

This study examined the sustainability competence and self-efficacy of Junior High School Science teachers and used the findings as a basis for developing a proposed Holistic Teaching Intervention. Anchored primarily in the GreenComp sustainability competence framework and contemporary perspectives on self-efficacy in Education for Sustainable Development, the study employed an explanatory sequential mixed-methods design. The quantitative phase involved 313 Senior High School Science students from two public secondary schools in the Division of Zamboanga City who assessed their former Junior High School Science teachers using a 48-item GreenComp-based survey questionnaire. The qualitative phase involved 15 Junior High School Science teachers who participated in focus group discussions. Quantitative data were analyzed using weighted mean and Pearson correlation, while qualitative data were examined through thematic analysis. Findings revealed High overall sustainability competence and High student-perceived self-efficacy, both with an overall mean of 3.08. A statistically significant moderate positive relationship was found between sustainability competence and self-efficacy ($r = .689$, $p = .000$), indicating that higher perceived competence tended to occur alongside greater perceived instructional confidence without implying causation. Sustainability competence differed significantly between the two schools, whereas self-efficacy did not. Teachers encountered challenges involving limited resources, time constraints, learner diversity, language barriers, financial limitations, workload, and differences in student preparedness. They sustained their competence and confidence through professional learning, collaboration, reflection, adaptive instruction, time management, and learner-centered practices. The study recommends strengthening contextualized sustainability education, sustained professional development, instructional support, and the implementation and evaluation of the proposed Holistic Teaching Intervention. The study is most directly aligned with SDG 4: Quality Education, particularly sustainability education and educator capacity-building, and SDG 13: Climate Action through the role of Science education in climate literacy and responsible environmental action. Its sustainability impact lies in strengthening long-term teacher capacity, institutionalizing Education for Sustainable Development, and supporting environmentally responsible, socially responsive, and contextually relevant Science education.

**Keywords:** Education; GreenComp Framework; Holistic Teaching Intervention; Self-Efficacy; Sustainability Competence; Teacher Professional Development; Science

## 1. Introduction

Education for Sustainable Development (ESD) has become increasingly important as education systems respond to interconnected environmental, social, economic, and institutional challenges. Contemporary sustainability education extends beyond the transmission of environmental knowledge; it aims to develop the knowledge, values, skills, dispositions, systems perspectives, future-oriented thinking, and capacity for responsible action needed to respond to complex sustainability concerns. UNESCO (2017) emphasizes that ESD should develop cognitive, socio-emotional, and behavioral learning outcomes, while UNESCO (2020) positions educator capacity-building as a priority for achieving ESD for 2030. Within basic education, teachers are central to translating sustainability policies and curriculum expectations into meaningful learning experiences. This responsibility is particularly relevant to Science teachers because environmental systems, climate change, biodiversity, resource use, technological development, public health, and human-environment relationships intersect substantially with science education. However, effective ESD requires more than disciplinary knowledge. Teachers must be able to connect scientific concepts with ethical, social, economic, civic, and future-oriented considerations while helping learners understand complexity and participate in responsible action (Jegstad et al., 2018; Stouthart et al., 2025; Uitto & Saloranta, 2017). The present study focuses on the sustainability competence and self-efficacy of Junior High School (JHS) Science teachers as perceived by Senior High School (SHS) students who had previously experienced their instruction. Sustainability competence is organized through the four interconnected areas of the GreenComp framework: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability (Bianchi et al., 2022). Self-efficacy, meanwhile, concerns teachers' perceived capability to enact sustainability-related instructional responsibilities effectively. Recent studies indicate that competence and self-efficacy are related but conceptually distinct dimensions of teacher development, making their joint examination particularly relevant to sustainability education (Handtke et al., 2022; Karvonen et al., 2023; Malandrakis et al., 2019). By examining these constructs together and contextualizing the quantitative evidence through the experiences of JHS Science teachers, the study seeks to generate evidence for a proposed Holistic Teaching Intervention responsive to actual instructional needs. Rather than treating sustainability education solely as environmental content, the study positions it as a multidimensional educational responsibility involving values, systems thinking, future orientation, collective participation, pedagogical confidence, and contextualized action.

Education has a critical role in enabling societies to respond to sustainability challenges because sustainable development requires changes not only in technology and policy but also in knowledge, values, decisions, and human behavior. UNESCO (2017) identifies sustainability competencies as cross-cutting capacities that enable learners to understand complex relationships among the Sustainable Development Goals (SDGs), while its ESD for 2030 roadmap emphasizes policy development, transformation of learning environments, educator capacity, youth participation, and local action as interconnected priorities (UNESCO, 2020). Thus, sustainability education requires learners and educators to move beyond awareness toward informed judgment and responsible action. This shift has strengthened interest in competency-based approaches to ESD. Brundiers et al. (2021) describe sustainability competence as involving interconnected capacities required to understand sustainability problems and contribute to their resolution. Imara and Altinay (2021) similarly conclude that teacher education must deliberately incorporate ESD competencies rather than assuming that teachers will acquire them incidentally. The development of competent teachers is therefore fundamental because curriculum intentions cannot automatically translate into effective classroom practices without adequate pedagogical preparation (Brandt et al., 2019). GreenComp provides a particularly useful contemporary structure for examining these capacities. Bianchi et al. (2022) organize sustainability competence into four interrelated areas containing 12 competencies: embodying sustainability values through valuing sustainability, supporting fairness, and promoting nature; embracing complexity in sustainability through systems thinking, critical thinking, and problem framing; envisioning sustainable futures through futures literacy, adaptability, and exploratory thinking; and acting for sustainability through political agency, collective action, and individual initiative. GreenComp is explicitly intended as a non-prescriptive reference framework that can be adapted across learning contexts rather than as a rigid curriculum or teacher-evaluation instrument. This holistic framing is important because sustainability problems cannot be understood adequately through isolated environmental concepts. Teachers must enable learners to examine relationships among ecological processes, human decisions, institutions, social inequalities, technologies, economies, and future consequences. Vesterinen and Ratinen (2024) found that systems thinking, collaboration, action orientation, values thinking, and futures thinking are recurring dimensions of sustainability competence in school education. However, these competencies are not equally represented in educational practice, suggesting the need for deliberate pedagogical development. Science education has significant potential to contribute to such development. Uitto and Saloranta (2017) found considerable differences among subject teachers in the extent to which they incorporated different sustainability dimensions, demonstrating that disciplinary specialization may shape ESD implementation. Jegstad et al. (2018) similarly showed that realizing ESD within science teacher education requires explicit integration of sustainability purposes into teaching rather than simply adding sustainability-related content. More recently, Stouthart et al. (2025) found that secondary Science teachers valued evidence-based reasoning, critical thinking, and systems thinking but differed in their willingness to address political, ethical, and value-laden dimensions of sustainability. These findings reinforce the importance of developing a holistic form of sustainability competence among Science educators. Competence alone, however, may not ensure classroom implementation. Teachers must also believe that they can successfully organize, facilitate, and sustain the corresponding instructional practices. Malandrakis et al. (2019) demonstrated that ESD-related teacher self-efficacy can be conceptualized across sustainability-relevant areas such as values and ethics, systems thinking, and action. Handtke et al. (2022) further developed empirical measures of self-efficacy for teaching ESD, demonstrating that confidence in carrying out ESD-related instructional tasks constitutes an important aspect of teacher preparation. Karvonen et al. (2023) found that sustainability competence and self-efficacy were meaningfully connected, particularly in relation to values, ethics, and systems thinking. These studies support examining competence and efficacy together rather than assuming that knowledge or competence automatically produces confident instructional enactment.

The literature highlights several key themes in sustainability education. First, sustainability competence is multidimensional, integrating systems thinking, values, future-oriented thinking, collaboration, and responsible action rather than environmental knowledge alone (Bianchi et al., 2022; Brundiers et al., 2021). Effective ESD teaching therefore requires both content knowledge and pedagogical competence (Brandt et al., 2019). Second, a knowledge-action gap remains, as favorable sustainability knowledge and attitudes do not always translate into actual behavior or classroom practice (Funa et al., 2022). Systems thinking, critical thinking, and problem framing are also essential for understanding complex sustainability issues (Bianchi et al., 2022; Vesterinen & Ratinen, 2024). Teacher self-efficacy further supports the implementation of sustainability-oriented instruction. Studies show that ESD-related beliefs, confidence, and competence are positively associated, although these relationships should not be interpreted as causal (Akça, 2019; Malandrakis et al., 2019; Handtke et al., 2022; Karvonen et al., 2023). Professional learning and collaboration likewise strengthen teachers' ESD competence, particularly through professional learning communities and shared practice (Isac et al., 2022). Finally, contextualized and action-oriented approaches make sustainability education more meaningful by connecting SDGs with authentic teaching, learners' experiences, and community issues (Guo et al., 2024; Cordova, 2024).

At the global level, the international sustainability agenda has increasingly positioned education as both a specific development goal and an enabling mechanism for achieving other SDGs. UNESCO's learning objectives for the SDGs explicitly connect sustainability education with cognitive understanding, socio-emotional development, values, collaboration, and behavioral action (UNESCO, 2017). The subsequent ESD for 2030 roadmap places particular emphasis on strengthening educators' capacities and transforming learning environments, affirming that the quality of sustainability education depends significantly on those responsible for implementing it (UNESCO, 2020). International evidence also reveals continuing implementation challenges. Subject specialization can make interdisciplinary ESD difficult, particularly in secondary education (Isac et al., 2022; Uitto & Saloranta, 2017). Science educators may be comfortable addressing scientific evidence while being less prepared to facilitate ethical, socioeconomic, political, or value-related sustainability issues (Stouthart et al., 2025). These findings are particularly relevant because authentic sustainability problems do not conform neatly to conventional disciplinary boundaries. In the Philippine basic education context, sustainability and climate concerns are already embedded within national educational priorities. The Department of Education (2022) explicitly affirmed the need to strengthen climate literacy and climate action within the K to 12 curriculum and identified Science among the subject areas through which climate change concepts are integrated. DepEd also recognizes climate change education as linked with ESD and Global Citizenship Education and emphasizes informed decision-making, stewardship, responsible resource use, learner participation, and community action. Empirical Philippine studies further demonstrate both progress and continuing needs. Funa et al. (2022), studying teachers and students within a contextualized sustainability setting, emphasized that sustainability knowledge and favorable attitudes do not automatically translate into behavior. Suaco (2024), examining secondary Science curriculum and Science teachers in the Cordillera Administrative Region, demonstrated the relevance of examining the incorporation of SDGs and teachers' knowledge and attitudes within Philippine secondary Science education. Cordova (2024) further showed that sustainability integration can be interdisciplinary and can support concrete action, participation, contextualized learning, and learner accountability. At the learner level, Padilla et al. (2025) examined SDG awareness among SHS students in a Philippine STEM school, underscoring the increasing relevance of sustainability within secondary science-oriented education. Despite these developments, Philippine evidence remains dispersed across curriculum integration, sustainability awareness, knowledge and attitudes, particular instructional interventions, and student outcomes. Comparatively less attention has been directed toward the combined examination of sustainability competence and self-efficacy among in-service JHS Science teachers, particularly using the newer GreenComp structure and within public secondary-school settings in Zamboanga City. The localized context is important because teacher competence is enacted within particular curricular, institutional, learner, resource, and community conditions rather than in an abstract educational environment.

The study is primarily anchored in the GreenComp: European Sustainability Competence Framework developed by Bianchi et al. (2022). GreenComp conceptualizes sustainability competence through four interconnected areas: Embodying Sustainability Values, Embracing Complexity in Sustainability, Envisioning Sustainable Futures, and

Acting for Sustainability. These dimensions emphasize values, systems and critical thinking, future-oriented thinking, adaptability, collaboration, political agency, and individual initiative, providing the study with a comprehensive framework for examining sustainability-oriented Science teaching (Bianchi et al., 2022). The study also draws on contemporary perspectives on ESD-related self-efficacy, which refer to teachers' perceived capability to perform sustainability-related instructional tasks. Previous studies have demonstrated the relevance of task-specific ESD self-efficacy and its association with sustainability competence (Malandrakis et al., 2019; Handtke et al., 2022; Karvonen et al., 2023). However, competence and self-efficacy are treated as related but distinct constructs, and their relationship is interpreted as associational rather than causal. Because the quantitative assessment was provided by SHS students, self-efficacy is interpreted as student-perceived manifestations of teachers' instructional confidence, persistence, adaptability, and willingness to facilitate sustainability-related learning. Student ratings can provide meaningful evidence of observable teaching practices but should not be considered equivalent to teachers' internal self-efficacy beliefs (Aditomo & Köhler, 2020). The qualitative perspectives of JHS Science teachers therefore serve to contextualize these student-rated patterns.

The literature reveals several gaps that justify the study. First, much ESD competence and self-efficacy research has focused on pre-service teachers, leaving the experiences of practicing teachers under real school conditions less examined (Akça, 2019; Brandt et al., 2019; Handtke et al., 2022; Imara & Altinay, 2021; Karvonen et al., 2023; Malandrakis et al., 2019; Isac et al., 2022). Second, sustainability competence and self-efficacy are often studied separately despite evidence that they are related and both important to effective sustainability teaching (Karvonen et al., 2023). Third, secondary Science education requires attention to sustainability dimensions beyond environmental knowledge, including systems thinking, ethics, future orientation, civic participation, and collective action (Uitto & Saloranta, 2017; Stouthart et al., 2025). A further gap is contextual. Although Philippine studies increasingly address sustainability education (Cordova, 2024; Funa et al., 2022; Padilla et al., 2025; Suaco, 2024), limited evidence examines the combined sustainability competence and self-efficacy of in-service JHS Science teachers in public secondary schools in Zamboanga City. Finally, assessment findings need to be translated into practical professional-development strategies. Thus, the study develops a proposed **Holistic Teaching Intervention** based on identified strengths, needs, challenges, and strategies, rather than treating it as an already tested intervention.

The study is most directly aligned with SDG 4 – Quality Education, particularly Target 4.7, which calls for learners to acquire the knowledge and skills required to promote sustainable development. UNESCO (2017) emphasizes that achievement of this target requires cognitive, socio-emotional, and behavioral learning, while UNESCO (2020) identifies educator capacity-building as a central ESD priority. By examining teachers' sustainability competence and their efficacy-related instructional capability, the study addresses the professional capacity required to translate Target 4.7 into classroom practice. The study also contributes to SDG 13 – Climate Action, particularly through the role of Science education in strengthening climate literacy, informed decision-making, adaptation thinking, and responsible environmental action. This alignment is especially relevant in the Philippine context, where DepEd has explicitly committed to strengthening climate education within the K to 12 curriculum and identifies Science as one of the areas through which climate concepts are taught (Department of Education, 2022). A secondary connection exists with SDG 12 – Responsible Consumption and Production, because GreenComp includes responsible resource use, sustainability values, systems understanding, and individual and collective action. The study also has relevance to SDG 17 – Partnerships for the Goals insofar as sustainable educational practice can be strengthened through teacher collaboration, professional learning communities, school leadership, and partnerships that support context-responsive sustainability initiatives. Isac et al. (2022) provide empirical evidence that teacher co-learning is positively associated with professional action competence in ESD. These alignments should not be interpreted as claims that the research directly measures achievement of the SDGs. Rather, the study contributes to educational capacities that support their advancement, particularly by strengthening the ability of Science teachers to facilitate sustainability-oriented learning.

The study contributes first to educational sustainability by focusing on teacher capacity as a long-term institutional resource. Sustainability education cannot depend solely on isolated activities, environmental celebrations, or short-term projects. It requires educators who can consistently integrate sustainability values, systems thinking, future thinking, critical inquiry, and action into ordinary teaching. Strengthening teacher competence and self-efficacy therefore supports the continuity and institutionalization of ESD. Second, the study contributes to environmental and ecological sustainability because Science teachers are important mediators of learners' understanding of natural systems, biodiversity, climate, environmental change, conservation, and responsible resource use. However, GreenComp extends this contribution from environmental awareness toward understanding interconnections, evaluating alternatives, anticipating consequences, and undertaking informed action (Bianchi et al., 2022). Third, the study contributes to social and community sustainability. GreenComp's emphasis on fairness, political agency, collective action, and individual initiative acknowledges that sustainability is simultaneously an ecological and social concern. Teaching sustainability therefore requires attention to inclusion, responsibility, participation, cooperation, and the distribution of consequences among people and communities. Such competencies can help learners view sustainability not only as a scientific problem but also as a shared civic responsibility. Fourth, the study supports institutional and professional sustainability by identifying areas that may guide continuing professional development. Evidence that teacher co-learning can strengthen ESD competence (Isac et al., 2022) indicates that sustainable improvement is more likely when professional development includes collaborative reflection, contextualized learning, shared instructional resources, and continuing support rather than one-time training. Finally, the research has multidisciplinary significance because contemporary sustainability problems require knowledge that crosses conventional disciplinary boundaries. Science provides essential evidence and understanding of natural and technological systems, but responsible sustainability decisions also require ethical reasoning, socioeconomic awareness, cultural sensitivity, governance, communication, and community participation. By integrating competence, self-efficacy, contextual challenges, teacher strategies, and intervention development, the study provides a broader foundation for sustainability-oriented education than approaches that focus exclusively on environmental knowledge.

The present study advances existing research by generating localized evidence on the sustainability competence and student-perceived self-efficacy of JHS Science teachers in two public secondary-school settings in the Division of Zamboanga City. SHS students serve as sources of evidence regarding instructional behaviors they previously experienced, while the participating JHS Science teachers provide contextual explanations of challenges and strategies through the qualitative component. The original manuscript explicitly identifies former SHS students as evaluators because of their direct experience with the participating teachers' classroom practices. The study does not assume that student perceptions provide direct access to teachers' internal psychological beliefs, nor does it infer causality from a statistical relationship between competence and self-efficacy. Instead, student assessments are used to examine observable manifestations of sustainability-related teaching, while teacher perspectives enrich interpretation of those patterns. This distinction strengthens the conceptual validity of the study and provides a more defensible basis for the proposed Holistic Teaching Intervention. Overall, the research addresses an educational sustainability problem at the intersection of Science education, teacher professional development, sustainability competence, self-efficacy, curriculum implementation, and institutional capacity-building. Its contribution lies not merely in describing whether teachers appear competent or confident, but in identifying how the multidimensional requirements of sustainability education can inform a context-responsive professional intervention for strengthening ESD in basic education.

## 2. Material and methods

### 2.1 Research Design

The study used an explanatory sequential mixed-methods design, consisting of a quantitative phase followed by a qualitative phase. The quantitative phase generated numerical evidence on the sustainability competence and self-efficacy of JHS Science teachers, while the subsequent qualitative phase provided deeper explanations of the patterns identified in the survey. This sequential arrangement allowed the findings of the first phase to inform the focus of the succeeding phase (Ivankova et al., 2016). Integration occurred through connecting, building, and interpretation. Consistent with the framework of Creswell and Plano Clark (2018), the quantitative findings were first examined to identify areas requiring further explanation. These findings informed the development of the FGD guide, which explored teachers' experiences, challenges, and instructional practices related to sustainability competence and self-efficacy. During interpretation, the quantitative findings and qualitative themes were compared side by side, allowing the qualitative evidence to explain and enrich the statistical results and provide the empirical basis for the proposed Holistic Teaching Intervention.

### 2.2 Locale of the Study

The study was conducted in two public secondary schools in the Division of Zamboanga City, identified as National High School A and National High School B to protect institutional identities. The schools were selected because they belonged to the district where the researcher also teaches, which facilitated coordination, requests for permission, and monitoring of participants' schedules.

### 2.3 Respondents of the Study

Two groups participated in the study in accordance with the explanatory sequential mixed-methods design. The quantitative phase involved SHS Science students who assessed the sustainability competence and self-efficacy of their former JHS Science teachers based on their classroom experiences. The total eligible student population was 1,665, consisting of 790 students from National High School A and 875 from National High School B. The qualitative phase involved 15 JHS Science teachers from the same schools, with nine teachers from National High School A and six from National High School B. These teachers participated in the FGDs to provide contextual explanations of their experiences, challenges, and strategies related to sustainability competence and self-efficacy. The use of separate participant groups allowed the quantitative data to provide measurable evidence from students while the qualitative data provided deeper explanations from the teachers themselves.

**2.4 Sample and Sampling Procedure**
The quantitative sample was determined using Cochran's Formula (Cochran, 1977). Using a 95% confidence level, $p = 0.50$, $q = 0.50$, and a 0.05 margin of error produced an initial sample estimate of 384.16. After adjustment for the finite population of 1,665 students, the required sample was approximately 312.4 and was rounded to 313 respondents. The 313 respondents were proportionately distributed between the two schools, resulting in 147 respondents from National High School A and 166 from National High School B. Simple random sampling was used so that each eligible SHS Science student had an equal probability of selection. This proportional allocation maintained each school's representation relative to its eligible student population. For the qualitative phase, total enumeration was employed because only 15 JHS Science teachers met the inclusion criteria. All nine eligible teachers from National High School A and all six from National High School B were therefore invited to participate in the FGDs. The inclusion of the entire eligible teacher population was intended to capture the range of relevant experiences and perspectives regarding sustainability competence and self-efficacy (Creswell & Poth, 2018).

**2.5 Research Instrument**
The quantitative instrument was a survey questionnaire patterned after the GreenComp framework and modified to suit the local context. The first part gathered demographic information, including the location and name of the school. The substantive portion measured the sustainability competence and self-efficacy of JHS Science teachers across four areas: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability. These covered valuing sustainability, supporting fairness, promoting nature, systems thinking, critical thinking, problem framing, futures literacy, adaptability, exploratory thinking, political agency, collective action, and individual initiative. The instrument contained 48 items, organized across the identified sustainability areas. A four-point rating scale was used. Mean scores from 3.25 to 4.00 were interpreted as Very High, 2.50 to 3.24 as High, 1.75 to 2.49 as Moderate, and 1.00 to 1.74 as Low. The ratings represented the students' perceptions of the degree to which their former teachers demonstrated sustainability competence and self-efficacy. The qualitative instrument consisted of FGD guide questions addressing the sustainability competence and self-efficacy of teachers in the participating schools. The guide was further informed by the quantitative findings so that teachers could explain the experiences, challenges, and instructional practices underlying the statistical patterns. For validity, the survey instrument was reviewed by three experts in sustainable education, including principals and supervisors. Their comments and recommendations were incorporated before the instrument underwent further evaluation. Pilot testing was subsequently conducted among 30 teachers who were not part of the study. Cronbach's Alpha yielded a coefficient of 0.974, indicating excellent internal consistency. According to George and Mallery (2019), reliability coefficients above .90 indicate excellent reliability.

**2.6 Data Gathering Procedure**
Data gathering commenced during the second semester of School Year 2024–2025 after approval was obtained from the Schools Division Superintendent. Participants were oriented through Google Meet, Zoom, and group chats regarding the purpose and procedures of the study. Questions were addressed during the orientation, informed consent was secured, and participants were informed that participation was voluntary and that they could withdraw without providing a reason or incurring any cost. The researcher administered the survey with the assistance of the school principals and coordinated with school heads to schedule data collection without disrupting regular classroom instruction. Respondents were given approximately 30 minutes to complete the questionnaire, and the researcher remained available for clarification without influencing their responses. A total of 313 students completed the survey, while 15 JHS Science teachers participated in the FGDs. The FGDs were conducted within the school premises and lasted approximately 30 minutes to one hour or until saturation of information. Participant responses were recorded, transcribed, translated into English, and categorized according to the objectives of the study. The school setting was used to provide participants with an appropriate environment for sharing their perspectives while maintaining confidentiality.

**2.7 Data Analysis Techniques**
The quantitative data were analyzed using descriptive and inferential statistical techniques. Weighted mean was used to determine the perceived levels of JHS Science teachers' sustainability competence and self-efficacy across the four GreenComp areas and their corresponding dimensions. Pearson r was used to determine the relationship between sustainability competence and self-efficacy. The qualitative data from the FGDs were analyzed using thematic analysis following the framework of Braun and Clarke (2006, 2021). The process involved familiarization with the verbatim transcripts, generation of initial codes, grouping of related codes into potential themes, review and refinement of preliminary themes, definition and naming of themes, and interpretation of the themes in relation to the quantitative findings. The resulting themes were used to explain the statistical findings and inform the proposed Holistic Teaching Intervention. The trustworthiness of the qualitative findings was addressed using the criteria of credibility, dependability, confirmability, and transferability proposed by Lincoln and Guba (1985). Credibility was supported through semi-structured FGDs, opportunities for participants to clarify their responses, and verbatim transcription. Dependability was addressed through systematic

documentation of data collection, transcription, coding, theme development, and interpretation. Confirmability was supported by grounding themes in participants' responses rather than the researcher's assumptions, while transferability was facilitated through descriptions of the setting, participants, and research context

**2.8 Ethical Considerations**

Ethics clearance was obtained from the Universidad de Zamboanga Ethics Review Committee after revisions arising from the proposal review. Permission was subsequently secured from the Zamboanga City Schools Division Superintendent and the principals of the participating schools. Participants received an orientation and informed-consent forms before data collection. The schools were coded by letters to preserve institutional confidentiality. Participation was voluntary, and refusal or withdrawal had no effect on participants' status, grades, evaluations, or reports. Respondents could discontinue participation or omit questions they did not wish to answer. Names were not included in the research records, and participants were identified only by letters or numbers. Electronic data were password-protected and stored on the researcher's server, while survey questionnaires and other records were maintained in a secure location and were to be disposed of after the researcher's graduation. Participants also retained the right to access the study findings.

## 3. Results and Discussion

### 3.1 Sustainability Competence of Junior High School Science Teachers

#### 3.1.1 Embodying Sustainability Values

The teachers obtained an overall weighted mean of 3.12, interpreted as High, for Embodying Sustainability Values. Promoting Nature recorded the highest mean at 3.18, followed by Supporting Fairness at 3.12 and Valuing Sustainability at 3.05. These results indicate that students consistently observed their former Science teachers demonstrating environmental stewardship, fairness, ethical responsibility, and sustainability-oriented values in classroom instruction and professional interactions. The stronger rating for Promoting Nature indicates that environmental responsibility was particularly visible in Science teaching, while the comparatively lower rating for Valuing Sustainability suggests opportunities to make reflective and value-based decision-making more explicit. Bianchi et al. (2022) identify valuing sustainability, supporting fairness, and promoting nature as interconnected components of sustainability competence. More recent Science education evidence also shows that teachers do not necessarily give equal emphasis to all sustainability competencies, particularly when values, ethical dilemmas, and broader social dimensions are involved (Stouthart et al., 2025). In the Philippine context, Funa et al. (2022) similarly demonstrated that favorable sustainability knowledge and attitudes do not automatically translate into observable sustainability behavior, underscoring the need to connect values explicitly with practice.

#### 3.1.2 Embracing Complexity in Sustainability

For Embracing Complexity in Sustainability, the teachers obtained an overall weighted mean of **3.08**, interpreted as High. Systems Thinking received the highest mean at 3.09, followed by Problem Framing at 3.08 and Critical Thinking at 3.06. The highest individual indicator, at 3.18, concerned recognition of the environmental, social, cultural, and economic repercussions of human activities, whereas recognition of unsupported sustainability claims or greenwashing received the lowest mean of 3.00. The results indicate that teachers were effective in helping learners recognize interconnected sustainability problems, although critical evaluation of sustainability claims remained comparatively less visible. GreenComp emphasizes systems thinking, critical thinking, and problem framing as complementary capacities necessary for understanding complex sustainability problems (Bianchi et al., 2022). Vesterinen and Ratinen (2024) likewise identified systems-oriented and critical competencies as important components of sustainability education in school settings. More recently, Stouthart et al. (2025) found that secondary Science teachers place considerable importance on evidence-based learning, while the treatment of ethical, political, and value-laden sustainability issues can vary considerably among teachers.

#### 3.1.3 Envisioning Sustainable Futures

The overall weighted mean for Envisioning Sustainable Futures was 3.06, interpreted as High. Exploratory Thinking obtained the highest mean at 3.07, followed by Futures Literacy at 3.06 and Adaptability at 3.05. Incorporating sustainability-related information from multiple disciplines obtained the highest indicator mean of 3.14, whereas examining sustainability issues from multiple perspectives obtained the lowest mean of 3.00. These findings indicate that teachers encouraged interdisciplinary exploration and consideration of long-term environmental and societal consequences, although deeper examination of alternative perspectives and future scenarios may be further strengthened. Bianchi et al. (2022) describe futures literacy, adaptability, and exploratory thinking as essential for envisioning sustainable futures. Brandt et al. (2019) similarly emphasize that competent ESD teaching requires opportunities for learners to engage with complex and future-oriented sustainability problems. Philippine evidence also supports contextualized and interdisciplinary teaching as an important means of making sustainability issues meaningful and relevant to learners (Cordova, 2024).

#### 3.1.4 Acting for Sustainability

Teachers obtained an overall weighted mean of 3.05, interpreted as High, for Acting for Sustainability. Individual Initiative recorded the highest mean at 3.12, followed by Collective Action at 3.08 and Political Agency at 2.96. The highest indicator, at 3.14, involved anticipating and influencing long-term transformations that support sustainability, whereas holding politicians accountable for unsustainable actions recorded the lowest mean of 2.94. The comparatively stronger Individual Initiative score suggests that sustainability was more readily expressed through personal and collaborative actions than through political or policy-oriented engagement. GreenComp explicitly treats individual initiative, collective action, and political agency as complementary forms of acting for sustainability (Bianchi et al., 2022). Stouthart et al. (2025) similarly showed that secondary Science teachers may differ in the extent to which they are comfortable addressing political, ethical, and value-related dimensions of ESD. Philippine findings also indicate that sustainability education benefits from opportunities that move beyond knowledge acquisition toward observable participation and action (Funa et al., 2022; Suaco, 2024).

#### 3.1.5 Overall Sustainability Competence

Across the four GreenComp competence areas, the teachers obtained an overall weighted mean of 3.08, interpreted as High. Embodying Sustainability Values received the highest mean of 3.12, followed by Embracing Complexity in Sustainability at 3.08, Envisioning Sustainable Futures at 3.06, and Acting for Sustainability at 3.05. The relatively small differences among the four areas indicate a generally balanced sustainability competence profile. The findings are consistent with the multidimensional nature of sustainability competence described by Bianchi et al. (2022), in which values, complexity, future-oriented thinking, and action are interconnected rather than isolated competencies. Vesterinen and Ratinen (2024) likewise emphasize that sustainability education requires the coordinated development of multiple competencies rather than concentration on content knowledge alone. UNESCO (2020) further positions teachers as central agents in transformative ESD, while Philippine secondary Science evidence confirms the continuing importance of integrating sustainability and the SDGs explicitly into Science curricula and instructional practice (Suaco, 2024).

### 3.2 Self-Efficacy of Junior High School Science Teachers

#### 3.2.1 Embodying Sustainability Values

The teachers' self-efficacy in Embodying Sustainability Values obtained an overall weighted mean of 3.11, interpreted as High. Promoting Nature received the highest mean of 3.20, followed by Supporting Fairness at 3.08 and Valuing Sustainability at 3.05. Recognition of human–nature interdependence received the highest individual mean of 3.31, interpreted as Very High, whereas linking ethical principles, conservation, and intergenerational welfare received the lowest mean of 2.94, although still interpreted as High. The findings suggest stronger perceived instructional confidence in environmental concepts than in complex ethical and intergenerational discussions. Contemporary research confirms that self-efficacy is particularly important for teachers' ability to implement ESD and facilitate sustainability-related learning experiences (Handtke et al., 2022). Karvonen et al. (2023) further found that self-efficacy related to sustainability values, ethics, and systems thinking is closely connected with sustainability competency. Recent evidence also indicates that teachers' sustainability-related practices themselves can reinforce ESD self-efficacy (Xu et al., 2025).

#### 3.2.2 Embracing Complexity in Sustainability

The overall weighted mean for self-efficacy in Embracing Complexity in Sustainability was 3.07, interpreted as High. Systems Thinking obtained the highest mean at 3.09, followed by Problem Framing at 3.07 and Critical Thinking at 3.04. Recognizing the environmental, social, cultural, and economic consequences of human activity recorded the highest individual mean of 3.16, whereas identifying unsupported sustainability claims or greenwashing recorded the lowest mean of 2.95. These findings indicate that teachers were perceived as confident in facilitating interconnected and systems-oriented learning but comparatively less confident in activities requiring sophisticated evidence evaluation. Handtke et al. (2022) emphasize that ESD teaching self-efficacy is multidimensional and should be examined in relation to specific instructional demands. Ghazali et al. (2024) likewise highlight critical reflection and contextualization as important dimensions of teacher self-efficacy in education for sustainability. Karvonen et al. (2023) further demonstrated a meaningful connection between systems-thinking self-efficacy and broader sustainability competency.

#### 3.2.3 Envisioning Sustainable Futures

For Envisioning Sustainable Futures, the teachers obtained an overall self-efficacy mean of 3.07, interpreted as High. Exploratory Thinking recorded the highest mean of 3.10, followed by Futures Literacy at 3.07 and Adaptability at 3.03. Relational and interdisciplinary thinking received the highest indicator mean of 3.19, whereas recognition of how personal preferences may influence anticipated future consequences recorded the lowest mean of 2.99. The findings indicate that teachers were perceived as confident in encouraging creativity and interdisciplinary exploration but somewhat less confident in facilitating reflection involving personal bias, uncertainty, and competing futures. GreenComp situates adaptability, futures literacy, and exploratory thinking as central to preparing learners for uncertain sustainability challenges (Bianchi et al., 2022). Kadji-Beltran (2024) further demonstrates the value of authentic and experience-based learning environments for developing sustainability teaching competence and confidence. Such approaches are especially relevant when future-oriented learning requires learners to work with ambiguity rather than predetermined answers.

#### 3.2.4 Acting for Sustainability

The teachers obtained an overall self-efficacy mean of 3.07, interpreted as High, for Acting for Sustainability. Individual Initiative had the highest mean of 3.11, followed by Collective Action at 3.08 and Political Agency at 3.01. The highest indicator, at 3.22, concerned preventive measures that protect human health and living organisms, while holding politicians accountable for unsustainable actions recorded the lowest mean of 2.94. The pattern again indicates greater perceived confidence in personal and collaborative sustainability action than in political or governance-related dimensions. Stouthart et al. (2025) found similar tensions in secondary Science education, where teachers may prioritize evidence-based instruction while approaching political and ethical sustainability issues more cautiously. Xu et al. (2025) further provide recent empirical evidence connecting teachers' pro-environmental behavior with stronger self-efficacy in ESD. Thus, strengthening authentic opportunities for civic and collective sustainability action may complement teachers' already strong confidence in individual environmental responsibility.

#### 3.2.5 Overall Self-Efficacy

Across the four competence areas, teachers obtained an overall self-efficacy mean of 3.08, interpreted as High. Embodying Sustainability Values received the highest mean of 3.11, while Embracing Complexity in Sustainability, Envisioning Sustainable Futures, and Acting for Sustainability each obtained 3.07. The minimal variation indicates a relatively balanced student-perceived self-efficacy profile. This pattern is consistent with contemporary ESD research showing that teachers' instructional confidence is linked with sustainability knowledge, professional preparation, and opportunities to apply sustainability pedagogy. Handtke et al. (2022) demonstrated the importance of ESD-specific self-efficacy in teacher education, while Yang et al. (2024) found meaningful relationships among sustainability knowledge, readiness, and self-efficacy for sustainability teaching. Kadji-Beltran (2024) likewise emphasizes that competence development and confidence can be strengthened together through authentic sustainability teaching experiences.

### 3.3 Relationship Between Sustainability Competence and Self-Efficacy

A statistically significant moderate positive relationship was found between overall sustainability competence and self-efficacy, with $r = .689$ and $p = .000$. Significant moderate positive correlations were also observed for Embodying Sustainability Values ($r = .661$), Embracing Complexity in Sustainability ($r = .656$), Envisioning Sustainable Futures ($r = .645$), and Acting for Sustainability ($r = .524$). The null hypothesis of no significant relationship was therefore rejected. The findings indicate that higher student-perceived sustainability competence tended to occur alongside higher student-perceived instructional confidence. This pattern is supported by Karvonen et al. (2023), who demonstrated that ESD-related self-efficacy beliefs are associated with sustainability competency. Similarly, Yang et al. (2024) found significant connections among teachers' sustainability knowledge, readiness, and teaching self-efficacy, while Akça (2019) reported relationships among ESD beliefs, self-efficacy, and solution-oriented capacities. These findings nevertheless support association rather than causation; competence and self-efficacy should therefore be understood as related but distinct constructs.

### 3.4 Differences According to School

For sustainability competence, School A obtained a mean of 3.15, compared with 3.00 for School B. The difference was statistically significant, $t = 2.574$, $p = 0.011$. Both schools nevertheless remained within the High descriptive category. For self-efficacy, School A obtained 3.12 and School B 3.03; the difference was not statistically significant, $t = 1.677$, $p = 0.095$. The difference in competence but not self-efficacy suggests that institutional context may affect opportunities to demonstrate sustainability competence without necessarily producing corresponding differences in perceived instructional confidence. Isac et al. (2022) found that teacher co-learning and professional collaboration are associated with stronger professional action competence in ESD. Choi and Kang (2019) likewise showed the relevance of cooperative professional development to teacher efficacy. Because the present study did not quantitatively measure leadership, resources, professional learning, or other organizational conditions, however, these factors should be treated only as plausible contextual explanations rather than causes of the school difference.

### 3.5 Challenges Encountered in Sustainability-Oriented Teaching

The qualitative data were analyzed thematically, and three major themes emerged: Instructional Challenges, Resource and Institutional Constraints, and Teacher and Learner Factors. These themes provided contextual explanations for the quantitative findings. In updating the methodological reference, Braun and Clarke (2021) provide a current guide for systematic thematic analysis and theme development.

#### 3.5.1 Instructional Challenges

Teachers reported learner diversity, poor reading comprehension, language barriers, insufficient instructional time, limited resources, and differences in learner readiness. These conditions required lesson modification, contextualization, simplification of complex sustainability concepts, differentiated instruction, and additional learner support. The findings demonstrate that ESD implementation depends not only on sustainability knowledge but also on teachers' ability to respond to heterogeneous learners and local classroom realities. Stouthart et al. (2025) similarly highlight practical barriers faced by secondary Science teachers when translating sustainability competencies into instruction. In the Philippines, Cordova (2024) emphasizes contextualized, participatory, and interdisciplinary approaches to SDG integration, while Suaco (2024) underscores the continuing need to strengthen sustainability integration in secondary Science education. These findings support UNESCO's (2020) emphasis on learner-centered and context-responsive ESD.

#### 3.5.2 Resource and Institutional Constraints

Participants reported limited instructional materials, internet connectivity, computers, financial resources, laboratory facilities, learning spaces, equipment, and instructional time. School B emphasized technology, infrastructure, and financial constraints more strongly, whereas School A more frequently described limited materials and the need to adapt available resources. These findings indicate that sustainability-oriented instruction is shaped partly by the conditions under which teachers work. UNESCO (2020) identifies transformed learning environments and educator capacity as priority areas for successful ESD implementation. Isac et al. (2022) likewise demonstrate that professional environments and opportunities for teacher co-learning matter for ESD competence, while Yang et al. (2024) emphasize readiness and capacity as important components of effective sustainability teaching. These contextual findings may help explain differences between schools, although they should not be interpreted as direct causal factors because the institutional variables were not quantitatively tested.

#### 3.5.3 Teacher and Learner Factors

Teacher and learner factors included workload, professional fatigue, motivation, learner engagement, reading comprehension, linguistic diversity, and differences in student participation. Heavy responsibilities reduced preparation time, while limited literacy and learner readiness required additional explanations, simplified activities, and differentiated support. The findings show that sustainability competence and instructional confidence were exercised under demanding rather than ideal conditions. Contemporary ESD self-efficacy research indicates that confidence is relevant to teachers' persistence and ability to address the specific demands of sustainability-oriented instruction (Handtke et al., 2022; Yang et al., 2024). Funa et al. (2022) further demonstrate in the Philippine context that sustainability-related knowledge and attitudes require supportive opportunities if they are to be translated into meaningful behaviors and practices.

### 3.6 Strategies for Sustaining Sustainability Competence and Self-Efficacy

Five major strategies emerged: Personal Well-being and Mindset, Continuous Learning and Professional Development, Time Management and Role Balancing, Goal Setting and Reflection, and Mastery, Feedback, and Adaptability. Together, these strategies show that the teachers sustained their practice through a combination of personal regulation, professional learning, reflective practice, collaboration, and instructional adaptation.

#### 3.6.1 Personal Well-being and Mindset

Teachers described emotional balance, optimism, mindfulness, physical activity, connection with nature, self-care, and maintaining a positive mindset as strategies for sustaining motivation and instructional performance. These practices helped them maintain competence and confidence despite demanding professional conditions. The findings indicate that perceived instructional confidence was supported not only by professional knowledge but also by teachers' capacity to remain resilient when confronting difficulties. Contemporary ESD self-efficacy research emphasizes that teaching confidence develops in relation to teachers' experiences and their perceived ability to manage demanding sustainability instruction (Handtke et al., 2022; Yang et al., 2024). Xu et al. (2025) further demonstrate that sustainability-related teacher behaviors and self-efficacy can reinforce one another, supporting the importance of teachers' own orientations and practices.

#### 3.6.2 Continuous Learning and Professional Development

Teachers sustained their competence through seminars, workshops, graduate studies, professional reading, observation of colleagues, community engagement, and continuous updating of instructional strategies. Professional learning was therefore viewed as an ongoing rather than one-time process. This finding is strongly supported by recent literature. Brandt et al. (2019) emphasize that ESD teacher competence develops through purposeful learning experiences rather than content exposure alone. Isac et al. (2022) found that teacher co-learning contributes to professional action competence, while Choi and Kang (2019) demonstrated the relevance of cooperative professional development to teacher efficacy. Thus, sustained professional learning may simultaneously support competence development and confidence in implementing ESD.

#### 3.6.3 Time Management and Role Balancing

Participants described organizing schedules, prioritizing instructional tasks, balancing personal and professional responsibilities, and maintaining work-life balance as important strategies for avoiding burnout and preserving instructional effectiveness. These organizational strategies enabled teachers to maintain professional learning and classroom preparation despite competing demands. Chen and Chen (2022) emphasize that sustainable professional learning involves continuous self-regulation, reflection, and professional development. Similarly, Choi and Kang (2019) show that sustained teacher development is strengthened by supportive professional conditions rather than isolated training experiences.

#### 3.6.4 Goal Setting and Reflection

Teachers used professional goal setting, planning, self-monitoring, and reflection to evaluate teaching practices and identify areas for improvement. These practices allowed participants to recognize effective strategies, address weaknesses, and adjust subsequent instruction. Chen and Chen (2022) identify reflective practice as an important mechanism for sustainable teacher learning and professional development. GreenComp similarly incorporates critical reflection and adaptability within sustainability competence (Bianchi et al., 2022). Consequently, reflection can help teachers connect classroom experience with future instructional decisions while supporting continuous competence development.

#### 3.6.5 Mastery, Feedback, and Adaptability

Teachers also sustained their competence and confidence through successful classroom experiences, constructive feedback, observation of colleagues, continuous learning, and adaptation to learners' needs. Participants reported refining instruction through experience and modifying strategies when classroom conditions changed. This theme closely corresponds with contemporary evidence on ESD self-efficacy and teacher development. Evans et al. (2016) showed that sustainability pedagogies can strengthen pre-service teachers' self-efficacy, while Isac et al. (2022) emphasize the contribution of collaborative learning to ESD professional competence. Kadji-Beltran (2024) further demonstrates that authentic, experience-based sustainability learning can strengthen teaching competence and confidence. Collectively, these studies support the finding that experience, collaboration, feedback, and adaptability help sustain both competence and instructional confidence.

### 3.7 Integration of Quantitative and Qualitative Findings

#### 3.7.1 Continuous Professional Learning and Sustainability Competence

The quantitative findings established a High overall level of sustainability competence, while the qualitative findings showed that teachers continuously developed this competence through workshops, graduate studies, professional reading, peer collaboration, classroom experiences, and reflection. This convergence indicates that sustainability competence was sustained through continuous professional growth rather than functioning as a fixed attribute. Brandt et al. (2019) emphasize the developmental character of ESD professional competence, while Isac et al. (2022) show that collaborative teacher learning supports professional action competence. These findings reinforce the importance of sustained rather than episodic professional development.

#### 3.7.2 Mastery, Resilience, and Self-Efficacy

Quantitative results showed High self-efficacy across all four GreenComp areas, while the qualitative results revealed that teachers maintained confidence through successful classroom experiences, positive mindset, feedback, reflection, time management, and adaptation. This integration is consistent with research showing that ESD self-efficacy is strengthened through meaningful preparation and experience. Handtke et al. (2022) emphasize the importance of domain-specific self-efficacy for teaching ESD, while Kadji-Beltran (2024) demonstrates how authentic sustainability learning experiences can strengthen teaching competence and confidence. Yang et al. (2024) similarly connects sustainability knowledge and readiness with teachers' self-efficacy.

#### 3.7.3 Interactive Development of Competence and Self-Efficacy

The quantitative analysis demonstrated a statistically significant moderate positive relationship between sustainability competence and self-efficacy. Qualitatively, teachers identified continuous learning, successful classroom implementation, collaboration, reflection, and feedback as experiences that simultaneously strengthened their competence and confidence. The integration therefore indicates that the two constructs are related and may develop interactively, although the correlational design does not establish that one causes the other. Karvonen et al. (2023) similarly demonstrated meaningful relationships between sustainability competency and ESD-related self-efficacy beliefs. Yang et al. (2024) further found that sustainability knowledge and readiness are associated with self-efficacy for teaching sustainability. These studies strengthen the interpretation of competence and self-efficacy as complementary but conceptually distinct aspects of sustainability-oriented teaching.

#### 3.7.4 Influence of Contextual Conditions

Although sustainability competence and self-efficacy were consistently rated High, the qualitative findings identified learner diversity, reading difficulties, language barriers, limited resources, financial constraints, insufficient technology, heavy workloads, and institutional limitations. These contextual conditions accompanied sustainability education implementation in both schools. These findings indicate that high levels of perceived competence and confidence were maintained despite considerable contextual constraints. UNESCO (2020) emphasizes that educator capacity must be supported by enabling learning environments, while Isac et al. (2022) demonstrate the importance of collaborative professional contexts in ESD. Philippine studies likewise underscore the value of contextualized sustainability instruction and stronger integration of sustainability within secondary education (Funa et al., 2022; Suaco, 2024). Together, the findings provide a defensible empirical basis for a Holistic Teaching Intervention that addresses teacher competence, instructional confidence, professional learning, and contextual support simultaneously.

## 4. Conclusion & Recommendations

The study concludes that Junior High School Science teachers demonstrated High sustainability competence and student-perceived self-efficacy across the four GreenComp areas of Embodying Sustainability Values, Embracing Complexity in Sustainability, Envisioning Sustainable Futures, and Acting for Sustainability. A significant moderate positive relationship was established between sustainability competence and self-efficacy, indicating that stronger perceived competence tended to be associated with greater perceived confidence in sustainability-oriented instruction. Despite these positive results, teachers encountered instructional and institutional challenges, including limited resources, time constraints, learner diversity, language barriers, financial limitations, workload, and varying student preparedness. Teachers sustained their competence and confidence through continuous professional learning, collaboration, reflective practice, adaptive and learner-centered instruction, and effective time management. Overall, the quantitative and qualitative findings demonstrate that sustainability competence and self-efficacy are complementary dimensions of sustainability-oriented teaching and provide the basis for the proposed Holistic Teaching Intervention.

The Department of Education and curriculum developers may strengthen Education for Sustainable Development in the Junior High School Science curriculum through contextualized instructional materials, curriculum guides, and policy support aligned with the GreenComp Framework, with emphasis on systems thinking, interdisciplinary learning, and action-oriented sustainability education. School administrators may sustain professional development through Learning Action Cell sessions, peer mentoring, collaborative lesson planning, and classroom-based sustainability projects while improving access to instructional resources and supporting interdisciplinary collaboration. Science teachers are encouraged to continue professional learning, reflective practice, and the use of contextualized, inquiry-based, learner-centered, and action-oriented strategies, while students may be given greater opportunities to participate in classroom and community sustainability activities. Future studies may replicate the research in other public and private secondary schools and employ longitudinal, multilevel, or structural equation modeling approaches, while the proposed Holistic Teaching Intervention may be implemented, monitored, and evaluated to determine its effectiveness and guide its further refinement.

The study was limited to Junior High School Science teachers and Senior High School Science students from two participating secondary schools in the Zamboanga City Schools Division, with sustainability competence and self-efficacy examined from the students' perspectives. The investigation was further delimited to the four GreenComp areas and their corresponding competencies and to the relationship between sustainability competence and self-efficacy; consequently, the findings should be interpreted within the specific participants, school settings, variables, and dimensions covered by the study.

## 5. Compliance with ethical standards

The author declares no conflict of interest. The study obtained ethics clearance from the Universidad de Zamboanga Ethics Review Committee and permission from the Zamboanga City Schools Division Superintendent and participating school principals. Participants were informed of the study's purpose and procedures, provided informed consent, and were assured that participation was voluntary, with the right to decline, skip questions, or withdraw without penalty. Confidentiality and anonymity were protected through coded identities, aggregated reporting, and secure password-protected data storage. These ethical safeguards applied to both the Senior High School Science student survey and the Junior High School Science teacher focus group discussions.

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