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RESEARCH ARTICLE

Science, Mathematics, ICT, and Engineering (SMIE) educators' strategies to contribute to the SDG No. 9 in Industry, Innovation and Infrastructure through the learning processes

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ABSTRACT

As learning across the world becomes more leaning in sustainability as its focus, it is crucial that educational instructions that are delivered in practice are aligned with the Global Sustainable Development Goal 9, which is Industry, Innovation, and Infrastructure. The current literature underscores the role of SMIE education in local development. However, there is still no practical or empirical evidence from these studies on how educators in practice incorporate SDG 9 principles and therefore foster the development of students' creativity, critical thinking, and problem-solving skills. This research used an exploratory qualitative approach with 18 teachers from public schools in Iloilo Province, Philippines, who were purposively chosen. These teachers were from the fields of Science, Mathematics, ICT, and Engineering. The study applied reflexive thematic analysis to reveal the connections among teaching methods, curriculum integration, and students' competencies and skills. The findings emphasize teacher-led strategies such as project-based learning, solving real-world problems, using technology, and collaborating across disciplines that not only prepare students for the challenges of sustainable industry and resilient infrastructure but also enhance their skills. In addition, some limitations of the study were the selection of public-school samples from only one province, the small sample size which may affect representation and dynamics, self-reported data, and the lack of students' perspectives which in turn affect generalizability. Furthermore, the non-specificity of the branches of SMIE as

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not indicating the dynamics was another limitation. It is recommended that future research on this subject matter be done over larger areas and different institutions involving more stakeholders and using either longitudinal or mixed methods.

Keywords: Science; Mathematics; Innovation; Computer; Information; Technology; Engineering

1. Introduction

The Sustainable Development Goals (SDGs) of the United Nations represent a global guide to solving economic, social, and environmental problems all over the world. One of the SDGs is the Sustainable Development Goal 9 (SDG 9) which is concerned with Industry, Innovation, and Infrastructure and it states the requirement for strong infrastructure to be built, for industry to be developed in an inclusive and sustainable way, and for innovation to be encouraged [1]. In contrast to other SDGs that are mainly concerned with social welfare or environmental protection, SDG 9 mainly deals with the core objectives of SMIE (Science, Mathematics, Information Technology and Engineering) education and its tasks. The students are involved in the process of technical development, creation of engineering solutions, and innovative problem solving, which are the key aspects focused by SDG 9. This goal profoundly affects teaching and learning, especially in the fields of science, mathematics, ICT (information and communications technology), and engineering. The mentioned areas of study are vital to provide pupils with the tech skills and problem-solving abilities that are necessary to be able to lead the way in sustainable industrial growth and innovations [2-5].

Despite the recognition by many as a potential area there is still a huge lack of research showing how educators of science, mathematics, ICT, and engineering apply the SDG 9 principles to their practices [6, 7]. Allocating considerable resources and efforts to ESD, still the transformation of sustainability concepts, particularly those concerning industry and infrastructure, into classroom practice in the case of SMIE educators is not very well understood [8, 9]. In particular, the skills-behavior of students in innovation, critical thinking, and problem-solving that are related to SDG 9 [10, 11, 12] are taught using any explicit methods. Furthermore, the obstacles that teachers encounter when teaching sustainability-related content as well as their strategies for overcoming these issues have not been well documented [13, 14].

The current study intends to identify the gaps that exist already by examining the methods used by the teachers in the areas of science, mathematics, ICT, and engineering to integrate SDG 9 in their teaching and learning activities. Further, the study will assess how far these methods support the students in gaining the skills that are needed for the development of sustainable industry and infrastructure. Teachers' instructional methodologies (independent variable), the integration of SDG 9 principles into the classroom content and teaching methods (intervening variable), and the students' skills development in innovation, critical thinking and problem-solving (dependent variables) are the main variables of the research. The primary guiding concepts of this study are sustainable education, SMIE pedagogy, ESD, competency-based learning, and aligning the curriculum with global goals [15, 16, 17].

In the Philippines, we recognize its national vision that prioritizes the transformation of industries, the increase of technologies, and the improvement of infrastructure. In this case, the implementation of SDG 9 in SMIE education becomes very important as it will equip future generations with the necessary skills to contribute not only to local development but also to global sustainability. Thus, a qualitative exploratory method will be adopted and data collection carried out through in-depth interviews with 18 carefully chosen teachers from four different subjects. The acquired data will undergo reflexive thematic analysis for the discovery of shared issues, teaching methods, and results as perceived by teachers [18]. This research intends

to reveal how by teaching, SMIE teachers play their part in SDG 9 and will also offer practical advice on how to integrate the sustainability concept into SMIE curricula [19, 20, 21].

2. Literature review

The Sustainable Development Goal (SDG) 9 highlights that infrastructure, industrialization, and innovation are the main features and drivers of long-term economic and social development. The literature also mentions education very often as the most important tool for the attainment of these goals, at times it is even represented as being the main mechanism through the development of certain technical competent and innovation-oriented learners [22]. However, the studies that have been conducted in this field may show the importance of education in connection to SDG 9 but it mostly remains at the level of norms and static situations. They only state what education should be achieving yet does not delve into how SDG 9 is being implemented in classroom practices. The research of Chavez and Lamorinas (2023) and Chavez, Del Prado, and Estoque (2023) confirms that there is a need to align pedagogy with global development goals, but it only gives a limited view of the teachers' everyday decisions regarding their instruction. This implies to the researchers a need for a study that does not confine itself to the conceptual and theoretical dimensions but rather investigates how educators incorporate SDG 9 principles into teaching approaches and strategies within the traditional SMIE disciplines of specific regions [23, 24].

Conversely, research that incorporates SDG 9 into SMIE education shows employing specific discipline strategies to link the curriculum with real-world challenges of industry and infrastructure. For instance, there is a science education study that suggests the use of systematic thinking and environmental sustainability as methods of understanding industrial processes [25], while the mathematical education literature mentions data modeling and quantitative reasoning as methods for infrastructure planning and resource optimization [26]. In the upper part, the ICT and engineering studies suggest problem-based learning, simulations, and design thinking as the main activities for innovation [27, 28]. Although the mentioned studies show a great deal of potential, they remain predominantly concerned with individual disciplines, thus providing segmented or fragmented insights instead of an overall picture of the SDG 9 integration across SMIE. Therefore, the comparative analysis of teachers' interpretations and enactments of SDG 9 across SMIE disciplines remains limited, which in turn adds to the relevance of this study in undertaking the cross-disciplinary inquiry.

Additionally, the existing body of literature almost unanimously agrees on the importance of innovation, critical thinking, and problem-solving as the key competencies for boosting and improving the attainment of SDG 9 goals. Trilling and Fadel (2009) maintain that these capabilities are essential for dealing with the global complexities, which is an aspect that has been particularly highlighted in the discussion of SMIE educational research favoring inquiry-based and experiential learning methods [29]. Research has shown that open-ended projects in engineering and ICT can mimic real problem situations, thus letting the students come up with solutions and participate in reflective learning [27,30]. Nonetheless, most of this research only concentrates on the students' outcomes while the pedagogical reasoning behind teachers' instructional choices remains underexplored. This situation results in a gap between the competencies that are recognized as being there and the teaching methods that bring them about. To bridge this gap, it is necessary to take a close look at educators' viewpoints and their practices.

Moreover, studies in different areas of education such as Science, Mathematics, ICT, and Engineering show that there are significant differences in the aspect of activeness, contextualization, and interdisciplinary teaching methods. For instance, science educators are using case studies and simulations to connect the concepts of sustainability to empirical inquiry [31], and mathematics teaching is constantly using real-world datasets for the purpose of analyzing trends in industry and environment. The literature on ICT and

engineering education mentions projects like mobile application development and capstone design where students are to interface with issues pertaining to the infrastructure that the industry and society face [27]. These practices illustrate an innovative approach to teaching, but it is a common trend in research to treat them as best practices without a thorough examination of their connection with and consistency to SDG 9 goals. Consequently, it is still ambiguous whether SDG 9 is an overt teaching framework or just a covert background on which the teaching takes place. This uncertainty highlights the necessity of investigating how teachers think about and deliberately include SDG 9 in their lesson planning.

In the context of the increasing alignment of SMIE education with SDG 9, literature focus has moved towards the assessment of sustainability competencies such as systems thinking, anticipatory skills, and integrated problem-solving. Redman and Wiek (2021) claim that these competencies cannot be evaluated through traditional examinations alone, thus supporting the proposal of a competency-based assessment (CBA) which includes self-perception tools, observational rubrics, and performance tests [32]. The introduction of Challenge-Based Learning (CBL) methods in engineering and technology education has opened new avenues for assessing the students' capacity to innovate while being subjected to real-world socio-technical constraints [33]. Likewise, Chavez et al. (2024) illustrate the way digital portfolios and reflective design journals can preserve the iterative and developmental characteristics of the innovation process specifically in ICT learning environments [27]. Even though these methods contribute to the assessment of sustainability-oriented learning outcomes, many of the previous studies remain confined to individual disciplines and varied methodologies. Hence, there is a lack of agreement regarding the integration of such assessment practices across SMIE domains to systematically measure the students' acquisition of the industrial, infrastructural, and innovation-related competencies as specified by SDG 9. This scenario points to the necessity of research that investigates the conceptions, implementations, and interpretations of assessment strategies related to SDG 9 by educators.

Even though the concept of Education for Sustainable Development has gained great support practically everywhere, literature continues to highlight the existence of barriers that prevent the inclusion of SDG 9 into classroom practices. One of the main challenges affecting the integration of SDG 9 into the curriculum includes curriculum inflexibility, lack of adequate professional development, and lack of proper resources [34]. Chavez (2020) and the team of Chavez, Gregorio, Araneta, and Bihag (2024) add that assessments create a lot of pressure and also time limitations discourage the use of innovative teaching methods [35, 36]. There are certain studies that mention adaptive strategies like working together and getting access to open educational resources [37], but these reports are mainly descriptive and do not investigate in-depth how teachers deal with institutional limitations. As a result, there is a lack of insight into the ways that teachers negotiate the different expectations set by the policy and reality in the classroom, which is the gap that this research tries to fill by putting the teachers' experiences first.

Moreover, the evaluation literature indicates that the classic methods of assessment are not enough to assess the abilities associated with innovation and sustainability. Researchers suggest using formative and performance-based evaluations, portfolios, and reflective tasks to gain a better understanding of how students apply their knowledge to the challenges of the real world [38]. The work of Chavez and Lamorinas (2023) demonstrates that such assessments can gradually unveil students' realization of sustainability [23]. Nevertheless, there is still limited empirical evidence regarding the way teachers select, design, and interpret these assessments in connection with SDG 9. This gap brings to light a more significant concern: although assessment frameworks are thoroughly developed, their practical connection with sustainability-centered teaching is still not fully investigated. Thus, analysis of teachers' assessment practices gives significant understanding of the day-to-day evaluation of SDG 9 competencies.

Collectively, the literature not only points out a strong theoretical background for the incorporation of SDG 9 in SMIE education but also at the same time indicates very significant points which are still not empirically understood especially in the field of teachers' specific instructional strategies, cross-disciplinary practices, and responses to implementation problems. The existing research mainly focuses on the ideal, the outcome, or a single type of pedagogy and does not give any hints about the effective way in which educators introduce SDG 9 in pupil's daily instruction. Thus, the investigation of the actual tactics of Science, Mathematics, ICT, and Engineering teachers gives a direct answer to these gaps. It also enriches the literature by providing an integrated, practice-centered view of SDG 9 implementation, hence broadening the understanding of education's role not only as a support mechanism but also as an active driver of sustainable industry, innovation, and infrastructure.

3. Methodology

3.1. Research design

This study employed an exploratory qualitative research design aimed at gaining in-depth insights into the strategies used by Science, Mathematics, ICT, and Engineering educators to integrate Sustainable Development Goal 9 (SDG 9) Industry, Innovation, and Infrastructure into their teaching practices. The exploratory approach is appropriate given the limited existing research on the pedagogical integration of SDG 9 within these disciplines and seeks to understand the nuanced ways educators nurture innovation, critical thinking, and problem-solving skills aligned with sustainable development.

3.2. Population and sampling

The study involved a purposive sample of eighteen (n=18) teachers specializing in Science, Mathematics, ICT, and Engineering extracted both from public schools from Iloilo Province, Philippines. Participants were selected based on their involvement in teaching these subjects and their willingness to share experiences regarding SDG 9 integration in their classrooms. Table 1 summarizes the demographic characteristics of the participants, including their subject specialization, years of teaching experience, and school type. This information provides context for understanding the range of perspectives and expertise represented in the study.

Table 1. Participant Demographics.

Participant No.	Specialization	Years of Experience	School Type
T1	Science	12	Public
T2	Mathematics	8	Public
T3	ICT	5	Public
T4	Engineering	11	Public
T5	Science	10	Public
T6	Science	9	Public
T7	Mathematics	15	Public
T8	Engineering	12	Public
T9	ICT	8	Public
T10	Mathematics	9	Public
T11	ICT	6	Public
T12	Engineering	13	Public
T13	Science	14	Public
T14	Mathematics	16	Public

Participant No.	Specialization	Years of Experience	School Type
T15	Mathematics	4	Public
T16	ICT	3	Public
T17	ICT	6	Public
T18	Engineering	8	Public

Table 1. (*Continued*)

Note: *T1 stands for Teacher 1 and so on*

3.3. Instrument

The primary data collection instrument was the semi-structured interview guide, developed to explore how educators design and implement teaching strategies that support SDG 9 within Science, Mathematics, ICT, and Engineering education. The instrument also aimed to uncover how these strategies nurture essential skills such as innovation, critical thinking, and problem-solving to prepare students for sustainable industry and resilient infrastructure challenges. Table 2 presents the list of guide questions used by this research study.

Table 2. Interview guide questions.

Objectives	Interview question
1. To explore the strategies employed by Science, Mathematics, ICT, and Engineering teachers in integrating SDG 9 within their learning processes.	1. Can you describe specific teaching strategies or activities you use that reflect the principles of SDG 9 (Industry, Innovation, and Infrastructure)?
	2. How do you connect your subject matter to real-world issues related to sustainable industry, innovation, or infrastructure?
	3. What challenges do you encounter when trying to integrate SDG 9 concepts into your teaching, and how do you address them?
2. To examine how teachers' strategies nurture innovation, critical thinking, and problem-solving skills that align with the goals of sustainable industry and resilient infrastructure.	1. In what ways do your teaching strategies encourage students to think critically about issues in industry, innovation, or infrastructure?
	2. Can you share an example of how your teaching helped students develop innovative or problem-solving skills related to sustainability?
	3. How do you assess or observe the impact of your teaching on students' ability to contribute to sustainable development goals in the future?

3.4. Data gathering procedure

The semi-structured interviews took place on an individual basis and were facilitated to generate descriptive narratives about the teachers' techniques associated with SDG 9, the difficulties they faced and the ways they encouraged the students' skills of being creative, thinking critically and solving problems. The guide for the interviews was meticulously created which matched the study's purpose and contained inquiries like asking the respondents to explain demonstrating specific teaching strategies or activities embodying the principles of SDG9; how they relate their topics to real-world problems particularly in the areas of sustainability in terms of industry, innovation or infrastructure; and the difficulties met when incorporating SDG9 concepts along with techniques used to deal with these difficulties. Furthermore, the teachers were invited to outline their pedagogical methods that promote the questioning of industry, innovation, or infrastructure issues; to cite instances of their teaching that enabled students to develop either innovative or problem-solving skills related to sustainability; and to indicate how they measure or perceive the influence of

their teaching on students' future capability to contribute to sustainable development goals. The interviews lasted for about an hour and were happening, as said, at the time and place of each participant's choice. Audio recording was done after obtaining informed consent.

3.5. Data analysis

With the approval of the participants, all interviews were recorded in audio format, and subsequently, they were transcribed literally, after which the analysis was conducted. The transcripts were subject to reflexive thematic analysis, starting from the first step of making oneself familiar with the data through reading the transcripts several times. The first codes were developed through line-by-line coding to get the patterns of the instructional strategies and the challenges and the pedagogical impacts that were associated with the SDG 9 integration. Then the related codes were grouped and refined into themes that reflected shared meanings across the participants' accounts, and this was done iteratively. Reflexivity was practiced during the process through analytic memo writing and peer debriefing, which allowed the researchers to critically review their assumptions and limit possible bias during coding and theme development.

3.6. Ethical considerations

Prior to the collection of data, ethical approval for the study was granted by the appropriate university research ethics review board. In addition, permission to carry out the research was obtained in writing from the Department of Education (DepEd)–Iloilo, and the principals of the chosen schools also granted their approval. Teachers in Iloilo Province, Philippines, who belong to the SMIE subject area, were well informed beforehand about the study's aim, method, and limit. Informed consent was given before the interviews started, and the participants were told that they could freely decide whether to take part or not, their answers would be kept secret, and they could drop out at any time during the research process.

4. Results

Research Objectives 1. To explore the strategies employed by Science, Mathematics, ICT, and Engineering teachers in integrating SDG 9 within their learning processes.

Question No. 1. Can you describe specific teaching strategies or activities you use that reflect the principles of SDG 9 (Industry, Innovation, and Infrastructure)?

Theme 1.1: *Integrating project-based learning*

Out of the (8) participants, all said that they use project-based learning as a way to make students more involved in the process of experimentation with renewable energy by such activities as making solar ovens or carrying out tests with biodegradable materials which are more eco-friendly and thus, are an important part of their competency development. The method of project-based learning applied here has had the positive effects of not only acquiring technical skills and enabling scientific inquiry among students but also of inspiring them to connect the industrial applications of sustainability trade with classroom activities. While the majority of the teachers are doing the basic renewable energy experiments, there are just a few of them who are going to the next level and who suggest students inquiring about alternative fuels or innovations in small scale, which in turn, promotes imagination and exposes students to new technologies coming up.

> "I integrate project-based learning where students design experiments related to renewable energy, such as building simple solar ovens or testing biodegradable materials."

> "I often allow some of my students to focus more on experimenting with alternative fuels, which encourages them to think about energy efficiency in new ways."

Theme 1.2: Challenging the students in solving real-world problems

A few six (6) respondents indicated that they organize activities that require students to use their technical knowledge to solve real problems, such as making low-budget and environment-friendly infrastructure models. These activities not only help students acquire the technical skills of problem-solving and innovating but also connect learning to the needs of society. The majority of the teachers are focusing on building the physical things with the students but a few also involve them in projects where they must discuss the properties of the materials, create the most efficient designs and come up with other options. This diversity gives the students a chance to examine multiple ways of doing things critically, learn the limitations, and think about the sustainability of the whole process.

> "In ICT courses, we design activities that challenge students to apply their technical knowledge to real-world problems, such as creating prototypes of low-cost, eco-friendly infrastructure like water filtration system using local materials or lightweight bridges from recyclable components."

> "We also encourage students to analyze case studies of engineering failures and propose improved designs, helping them understand the responsibility of building safe and resilient infrastructure."

> "Sometimes, other projects involve students redesigning local infrastructure models, prompting them to compare solutions and discuss which materials or methods are more sustainable."

Theme 1.3: Using real-world data to create an activities

Four (4) participants mentioned that they frequently utilize data from the real world, such as carbon emissions, transportation costs or construction supplies, to develop problem-solving activities. They show students how math is applied in innovation through modeling and by using statistics in the logistics, construction, and environmental management sectors. They also present optimization problems where students must find the trade-offs among efficiency, cost, and sustainability just like the engineers and inventors do. It was also mentioned that through integration of projects where students use different levels of math to come up with plans for the buildings, predict the use of resources, or assess energy efficiency, they further enhance the learning of their students. By presenting mathematics as a means of understanding systems and solving real-world problems, the teachers are equipping the students with the necessary skills of critical thinking and problem-solving that are by no means disconnected from the process of creating strong and eco-friendly industries.

> "I often use real-world data sets, such as carbon emissions, transportation costs, or construction materials, to create problem-solving activities."

> "We also integrate modeling projects where students apply geometry, algebra, and calculus to design structures, predict resource use, or evaluate energy efficiency."

Question No. 2. How do you connect your subject matter to real-world issues related to sustainable industry, innovation, or infrastructure?

Theme 2.1: *Emphasizing sustainability and innovation*

Seven (7) participants reported that they stress the importance of environmental sustainability by connecting the teaching of ecosystems and biodiversity with discussions on renewable energy, waste management, and climate change. For instance, while teaching photosynthesis, they relate it to biofuels and the role of plant-based solutions in sustainable industries. Furthermore, the educators mentioned that they frequently take advantage of case studies and applied research to illustrate that scientific knowledge is a factor in sustainable innovation, no matter how it is manifesting, in electric vehicle development, smart city construction, or climate-resilient infrastructure creation, they properly substantiate each scientific principle to support the industry's or society's long term solution.

> "I emphasize environmental sustainability by linking lessons on ecosystems and biodiversity to discussions about renewable energy, waste management, and climate change."

> "I often use case studies and applied research to demonstrate how scientific knowledge drives sustainable innovation. "

Theme 2.2: *Integrating concepts of green and resilient infrastructure.*

Nine (9) participants in total indicated that they relate structural design classes with green infrastructure by presenting case studies of earthquake-resistant buildings that are constructed from eco-friendly materials. Students perceive that the engineering field deals with the production of structures that are safe and thus environmentally friendly. Besides, the students pointed out that they are depicting optimizations in the production process and lean manufacturing as industrial practices that can reduce waste, lower energy use, and improve turnaround. When they do this, they are not only teaching students that engineering is about solving technical problems but also about being the source of innovation that makes it possible for industries and infrastructures to be sustainable and future ready all at once.

> "I connect structural design lessons to green infrastructure by showing case studies of earthquake-resistant buildings that also use eco-friendly materials."

> "I highlight process optimization and lean manufacturing as ways industries can minimize waste, reduce energy consumption, and improve productivity."

Theme 2.3: *Highlighting how technology supports innovation*

Two (2) respondents indicated that the teaching of networks and systems in their classes is done in such a way that ITC's contribution to sustainable industries is made clear through cloud computing, for instance, the reduction of paper usage, AI usage, and the blockchain technology for creation of transparent supply chains. Lessons on database management are linked to systems that monitor carbon footprints, and the logistics are optimally managed and renewable energy sources are managed, thus showing the role of ICT in both efficiency and eco-friendly operations. Moreover, they pointed out that through systems analysis and design, the students are to come up with such solutions as waste tracking platforms, smart transport applications, and renewable energy management systems. In summary, these methods provide students with the idea of ICT being more than just a technical field, but a crucial factor in the sustainability of industries and innovations as well.

> "When teaching networks and systems, I highlight how ICT supports sustainable industries through innovations like cloud computing for reducing paper use, AI for energy efficiency, or blockchain for transparent supply chains."

> "Through systems analysis and design, students explore solutions like waste tracking platforms, smart transport applications, and renewable energy management systems."

Question No. 3. What challenges do you encounter when trying to integrate SDG 9 concepts into your teaching, and how do you address them?

Theme 3.1: *Making SDG 9 relevant everyday*

One (1) of the teachers and four (4) science-related participants stated that one of the difficulties is integrating SDG 9 with everyday science lessons. Students usually consider science purely theoretical, therefore linking it to industry and infrastructure might be like a forced bridge. The teachers involved in the discussion solve the problem by doing case studies on renewable energy projects or waste-to-energy technologies to demonstrate how scientific concepts are at the very heart of innovation and sustainable infrastructure development. Besides, they talked about yet another problem that SDG 9 very often needs interdisciplinary thinking, but the students are still accustomed to handling science as a separate subject. Some of them go as far as joining forces with mathematical or engineering colleagues for project-based activities, like building models of eco-friendly houses where scientific concepts are used. The teachers have also identified that students sometimes perceive the SDGs as too global or remote, thus they point out community-driven innovations, for example, solar lamps in off-the-grid places or biogas plants for feeding livestock, to make science and the building of sustainable industries and infrastructure more relevant and localized..

> "One challenge is making SDG 9 feel relevant to everyday science lessons. Students often see science as purely theoretical, so linking it to industry and infrastructure can feel forced."

> "Another difficulty is that SDG 9 often requires interdisciplinary thinking, yet students are used to treating science as a stand-alone subject."

Theme 3.2: *Lack of laboratory classrooms and equipment*

Altogether ten (10) people said that the major, if not the only, concern in the application of SDG 9 was the difference between school knowledge and reality concerning infrastructure projects. The majority of them pointed to the unavailability of modern facilities and equipment as the main reason for the slow technological progress, as the students were mostly learning with obsolete tools. To counter this problem, the students are encouraged to think of new uses for the materials available or to redesign them, and also to get acquainted with the simulation software which imitates present-day engineering practices. Moreover, they pointed out that further, the students were not able to really appreciate mathematical formulas or learn technical concepts relating to industry practices unless they were given some graphical representation of the terms used, which, in this case, they did through the illustration of bridges, transport systems or green buildings that combine these principles in real projects. To change this mindset, they inform the students how international companies and even local firms have begun to use SDG frameworks in guiding their designs. Thus, they realize that SDG 9 is not only an academic issue but rather a standard that has been widely accepted in the profession.

> "We often find that the biggest hurdle in integrating SDG 9 is bridging the gap between classroom theory and real-world infrastructure projects. Many point out that the lack of updated laboratory equipment makes it difficult to talk about innovation, since students are often practicing with outdated tools."

> "Teachers also highlight the challenge of helping students see the connection between mathematical formulas or technical concepts and actual industry practices, which they address through case studies of bridges, transport systems, or green buildings that apply these principles in real projects."

Theme 3.3: *Access to updated technology*

A group of Seven (7) participants, all of them teaching courses in ICT and engineering, stated that one of the biggest problems is the inability to get access to the latest and most advanced technology. Teaching innovation seems to be more like a joke if they are going to be using outdated software and hardware. To handle this situation, they place the emphasis on problem-solving and adaptability rather than on the tools per se. For instance, they allow students to visualize cloud-based systems or to investigate open-source platforms so that they can still get involved with the ideas of digital innovation and eco-friendly industry. Moreover, they also mention that very often students think of ICT only in terms of programming or hardware, without seeing its bigger picture in innovation and infrastructure, so they include illustrations like smart cities, AI for energy efficiency, and blockchain for transparent supply chains. To make these lessons more engaging and easier to relate to, they draw attention to local tech startups and community-based ICT projects, showcasing to students that digital innovation is not only a global occurrence but also taking place in their own neighborhoods.

> "A big challenge is access to updated technology. Teaching innovation feels ironic when we use outdated software and hardware. I address this by focusing on problem-solving and adaptability rather than specific tools."

> "Teachers also note that students often see ICT only in terms of programming or hardware, without realizing its larger role in innovation and infrastructure, so they integrate examples like smart cities, AI for energy efficiency, and blockchain for transparent supply chains."

Research Objectives 2. To examine how teachers' strategies nurture innovation, critical thinking, and problem-solving skills that align with the goals of sustainable industry and resilient infrastructure.

Question No. 1. In what ways do your teaching strategies encourage students to think critically about issues in industry, innovation, or infrastructure?

Theme 1.1: *Connecting lessons to real-world challenges*

Ten (10) participants expressed that they encourage students to think critically about industry, innovation, and infrastructure by connecting lessons to real-world challenges. For example, when they study energy, they ask students to compare fossil fuels and renewable sources not just in terms of efficiency, but also long-term social and ecological impact. This way, they learn that innovation isn't only about new discoveries but about balancing progress with responsibility. Additionally, they mentioned that they push them to ask "what if" questions that link simple experiments, such as testing material strength, to larger concerns in infrastructure and environmental responsibility. This way, they begin to see science not just as knowledge, but as a framework for making thoughtful, responsible decisions about innovation and progress.

> "I encourage students to think critically about industry, innovation, and infrastructure by connecting lessons to real-world challenges. For example, when we study energy, I ask students to compare fossil fuels and renewable sources—not just in terms of efficiency, but also long-term social and ecological impact."

> "I push them to ask "what if" questions that link simple experiments, such as testing material strength, to larger concerns in infrastructure and environmental responsibility."

Theme 1.2: *Designing problem-solving tasks same as in real-world context*

Six (6) participants expressed that they encourage students to think critically about industry, innovation, and infrastructure by framing problems in real-world contexts. Instead of solving equations in isolation, they design tasks that mirror practical challenges such as optimizing resources, analyzing risks in construction projects, or managing financial data for sustainable initiatives. Students are asked not only to find the correct answer but also to justify their methods and consider how different approaches could lead to varying outcomes. Additionally, they mentioned that they also introduce open-ended problems where multiple solutions are possible, prompting them to weigh efficiency, accuracy, and practicality skills that are crucial in industries where decisions affect infrastructure and innovation. By emphasizing reasoning, communication of ideas, and application of concepts beyond the classroom, students begin to see mathematics as a powerful decision-making tool for building sustainable and forward-looking solutions.

> "Instead of solving equations in isolation, I design tasks that mirror practical challenges such as optimizing resources, analyzing risks in construction projects, or managing financial data for sustainable initiatives."

> "I also introduce open-ended problems where multiple solutions are possible, prompting them to weigh efficiency, accuracy, and practicality, skills that are crucial in industries where decisions affect infrastructure and innovation."

Theme 1.3: *Using case studies of successful and failed projects*

Two (2) respondents emphasized using case studies of both successful and failed projects to develop students' analytical and critical thinking skills. Most teachers focus on failures to highlight lessons learned and prevent future errors, while a few also use debates and discussions around alternative approaches. These strategies encourage students to think critically, weigh different outcomes, and understand the broader social and environmental impacts of innovation.

> "My strategy is to bring in case studies of both successful and failed projects. Students analyze why certain infrastructures collapsed or why some innovations transformed industries."

> "I also present case studies where students debate alternative approaches, which helps them consider multiple perspectives on innovation and accountability."

Question No. 2. Can you share an example of how your teaching helped students develop innovative or problem-solving skills related to sustainability?

Theme 2.1: *Using hands-on projects in class*

Four (4) participants expressed that they had students design mini ecosystems in recycled containers. They had to balance plants, soil, and water sources to keep the systemalive for weeks. Many experimented with natural filters or light adjustments. This hands-on project made them think like scientists, testing, adjusting, and problem-solving while seeing how small innovations can support sustainability in real life. The trial-and-error process made them realize that sustainability is continuous improvement, not just a one-time solution. Additionally, they mentioned that they tasked students to build small wind turbines from recycled materials. They measured how much energy they could generate under different wind conditions. It

pushed them to innovate with limited resources and to see renewable energy not as an abstract concept but as something they could create. Through these varied approaches, Science teaching not only deepens content knowledge but also fosters creativity, critical thinking, and a problem-solving mindset grounded in sustainability.

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Theme 2.2: *Challenge students to design digital solutions*

Eight (8) respondents expressed that they guided students in creating an app prototype that encourages waste segregation in their community. They brainstormed features like barcode scanning for recyclables and gamified rewards. The project required coding logic, but more importantly, it pushed them to innovate digital solutions for environmental challenges they face daily. Students were tasked to design digital solutions that promote sustainability while sharpening their problem-solving skills. Additionally, they mentioned that these activities require students to combine technical skills in coding, data management, and digital design with creativity and social responsibility. By integrating sustainability challenges into ICT learning, they show students that technology is not just about innovation for convenience, but also about crafting meaningful solutions that address pressing environmental problems.

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> "These activities require students to combine technical skills in coding, data management, and digital design with creativity and social responsibility."

Theme 2.3: *Creating a low cost but strong model*

All Six (6) teachers related to engineering expressed that they challenged students to create a model of a low-cost, flood-resistant house using locally available materials, which sharpens both their technical and creative thinking. Collaborative activities are also highlighted, such as team-based challenges to design transport systems or water-saving irrigation models that balance functionality with affordability. Additionally, they mentioned that students compare the environmental impact of traditional materials with eco-friendly alternatives like bamboo or recycled plastics. These hands-on experiences shared by them encourage students to see engineering not only as solving technical problems but as innovating for real-world sustainability, preparing them to create infrastructures that are both practical and environmentally responsible.

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> sustainability, preparing them to create infrastructures that are both practical and environmentally responsible."

Question No. 3. How do you assess or observe the impact of your teaching on students' ability to contribute to sustainable development goals in the future?

Theme 3.1: *Student's curiosity and problem-solving skills*

Ten (10) participants, which is almost the majority of the sample, expressed that they observe the impact of their teaching through the ways students extend their curiosity beyond the textbook and apply problem-solving skills in meaningful contexts. For example, when they design eco-friendly experiments, propose waste reduction strategies, or select research topics such as renewable energy, water conservation, or biodiversity protection on their own, it shows them that they are internalizing the value of sustainability. Additionally, they mentioned that they look at how students respond to real-world case studies we analyze. If they can propose evidence-based solutions that balance human needs and environmental care, they know they're beginning to develop the mindset needed to support SDGs in the future. Finally, when analyzing case studies, their ability to propose evidence-based solutions that balance human needs and environmental care reassures them that they are developing the mindset and competencies needed to meaningfully contribute to the Sustainable Development Goals in the future.

> "I observe the impact of my teaching through the ways students extend their curiosity beyond the textbook and apply problem-solving skills in meaningful contexts."

> "I look at how students respond to real-world case studies we analyze. If they can propose evidence-based solutions that balance human needs and environmental care, I know they're beginning to develop the mindset needed to support SDGs in the future."

Theme 3.2: *Observing how students integrate sustainability into their designs*

Four (4) participants shared that they see the impact when students can integrate sustainability into their engineering designs and problem-solving approaches. In project-based assessments, they ask them to justify material choices or explain how their structures can minimize environmental impact. The way they now talk about resilience, efficiency, and green engineering makes me confident that they'll be able to design infrastructures that align with global sustainability goals in the future. Additionally, they mentioned that they also notice their progress when they work collaboratively to design models or prototypes that address real-world issues such as disaster-resilient housing or water-efficient systems, showing both technical competence and social responsibility. When students articulate how their designs can contribute to long-term community welfare and environmental care, which assures them that they are preparing to become engineers who can actively support the Sustainable Development Goals.

> "I see the impact when students can integrate sustainability into their engineering designs and problem-solving approaches."

> "I also notice their progress when they work collaboratively to design models or prototypes that address real-world issues such as disaster-resilient housing or water-efficient sytems, showing both technical competence and social responsibility."

Theme 3.3: *Students applying mathematical reasoning to real-world context*

A total of Four (4) respondents mentioned that they observe the impact of their teaching through the way students apply mathematical concepts to real-world sustainability challenges. When students use data analysis to track energy consumption, model population growth against resource availability, or calculate carbon footprints, they can see that students are moving beyond abstract and problem-solving meaningful applications. Additionally, they shared that they also notice their progress when students engage in collaborative tasks, such as designing statistical surveys on community waste management or optimizing resource allocation in hypothetical projects, which show both critical thinking and creativity. While most assessment focuses on group performance, three (3) teachers noted that individual student problem-solving often reveals complementary insights. These observations underscore the importance of combining collaborative and independent tasks to capture a full picture of student competency development.

> "I observe the impact of my teaching through the way students apply mathematical concepts to real-world sustainability challenges."
>
> "Some students demonstrate stronger problem-solving individually rather than in groups, which highlights the need to balance collaborative and independent activities."
>
> "I also notice their progress when students engage in collaborative tasks, such as designing statistical surveys on community waste management or optimizing resource allocation in hypothetical projects, which show both critical thinking and creativity."

5. Discussion

The present study was conducted to investigate the different ways that Science, Mathematics, ICT, and Engineering educators are integrating the Sustainable Development Goal (SDG) 9, which concerns industry, innovation, and infrastructure. The results of the study showed that teachers are applying context-driven, interdisciplinary methods to teach the subject and thus sharing with students not only the technical knowledge but also the principles of sustainability, making the students capable of contributing to SDG 9 in a meaningful way. This is in line with earlier studies that have pointed out the importance of SMIE education in developing innovation-oriented learners who can address the real-world challenges of industry and infrastructure [22, 23].

Moreover, educators from various disciplines pointed to project-based learning, resolving real-life issues, and using technology as their key approaches. On top of these, the Science teacher connected environmental ideas with industrial innovations, the math teacher used actual data for infrastructure modeling, the ICT teacher permitted digital solution development for sustainability practices, and the Engineering teacher guided the team in creating durable infrastructures. All these activities are not only confirming but also extending previous studies that conclude inquiry-based and experiential learning as the best ways to develop the core competencies for digital SDG 9, such as critical thinking, problem-solving, and innovation [29, 27].

At the same time, the study uncovered the fact that educators deliberately nurture students' creativity and analytical skills through teamwork projects, non-restricted tasks, and contemplation activities. This is indeed the case in the realm of competency-based education where the learning outcomes are not only about acquiring knowledge but also about students' ability to apply skills in authentic contexts [32]. For example,

ICT learners developed app prototypes to address local environmental issues, echoing prior work on digital portfolios and challenge-based learning frameworks as tools for assessing iterative problem-solving [33].

Teachers have voiced their worries and frustrations about the difficult system in which they operate with limited laboratory resources, outdated technology, and rigid curriculum that have been pointed out by several studies as major barriers [34, 36]. However, they resorted to the use of techniques not only collaborative lesson planning, but also simulations and open educational resources, which are the practical negotiation between the given institutional limitations and the pedagogical goals. Thus, their findings are not only consistent, but they also add up to the discussion of the previous literature by giving sample empirical data on the SDG 9 conceptualization by the teachers in their constrained realities, and on the convergence of the policy expectations and the classroom practice.

Moreover, formative and performance-based assessments were recognized as the main method to indicate the students' problem-solving, creativity, and sustainability awareness. This is what the literature has been saying all along about the need for alternative assessment in the form of reflective journals and project portfolios to reveal the non-examined skills [38, 23]. The teachers saw the students putting their technical knowledge into the practice of producing sustainability innovations, which is an indication that these assessments are very effective in exposing the students' potential contributing skills to the sustainable industry and infrastructure, thus closing the gap between teaching methods and demonstrated abilities.

This research has a limitation regarding the teachers from a single province in the Philippines which could affect the drawing of general conclusions. The data was collected through self-reports, which might have led to the occurrence of social desirability bias, and students' perspectives were not part of the study, which reduced understanding of the impact of instruction from the students' point of view. Another thing is that the sample size of $n=18$ does not suffice most educators in the field, considering also the fact that all participants were extracted from public school settings only, limiting the study from private school insights. Future investigations should consist of more extensive geographic samples, various stakeholders, and longitudinal designs in order to confirm and evaluate the lasting effects of SDG 9 integration.

The study highlights the function of the STEM (Science, Technology, Engineering, and Mathematics) educators in the realization of SDG 9. The teachers not only connect theory with practice by developing necessary skills and adapting to contextual difficulties but also help their students to become the ones who contribute actively to the future industry and infrastructure that would be both resilient and sustainable. These results not just verify the previous literature but also add to the understanding of the cross-disciplinary teaching methods and their real-world applicability in promoting sustainable development.

6. Conclusion

The researchers of this study investigated the implication of SDG 9 by the integration of the learned disciplines into classes, particularly Science, Mathematics, ICT, and Engineering, and how this led to the enhancement of students' skills in innovation, critical thinking, and problem-solving. Among the revealing findings were the effective involvement of teachers in project-based learning, solving real-world problems, and conducting hands-on activities in making learning relevant and sustainability-focused while connecting lessons to practical issues like renewable energy, green infrastructure, and digital inventions. The teachers, even amidst the challenges of using old equipment, a lack of access to technology, and the abstract nature of SDG 9, have come up with various ingenious methods like simulations, cross-discipline collaboration, and bringing the community into the examples which enrich the subject matter understanding and also give students the power to create real-world solutions and critically assess the social and environmental effects of

the new things that emerge. Policy-wise, it is recommended by the research that SDG 9 should be recognized as an official part of the national SMIE curriculums, there should be continuous training for the teachers about the sustainability teaching methods, and the laboratories as well as the ICT resources should be kept updated so that they are accessible. For future research, it is suggested to conduct longitudinal studies that track student outcomes, employ mixed methods, and assess competency development to evaluate the lasting impact of SDG 9 integration on learners' skills and sustainability mindset. To sum up, by the deliberate integration of sustainability in SMIE teaching, the students will be equipped with the tools and the right mentality to actively engage in the making of a future that is more durable, creative, and sustainable.

Conflict of interest

The authors declare no conflict of interest

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