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RESEARCH ARTICLE

Harnessing Innovative Traits of ICT, Math, Science, and Engineering Learners Contributory to Sustainable Development Goals

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ABSTRACT

In an era where education plays a pivotal role in achieving the United Nations Sustainable Development Goals (SDGs), there remains a limited understanding of how learners in ICT, Mathematics, Science, and Engineering cultivate and apply innovative traits toward sustainability-oriented solutions. Existing literature primarily focuses on the integration of sustainability concepts within curricula, yet the specific learner-driven innovative behaviors that contribute to sustainable development remain underexplored. Anchored on Social Cognitive Theory [1], which emphasizes the interaction of personal, behavioral, and environmental factors in shaping innovation and problem-solving, this study explores how learners in STEM-related disciplines demonstrate and apply innovative traits in addressing sustainability challenges. Using an exploratory qualitative design, twenty (n=20) ICT, Math, Science, and Engineering learners will participate in one-on-one interviews to elicit their experiences, strategies, and reflections. Data will be analyzed through reflexive thematic analysis, allowing for the emergence of nuanced themes related to creative problem-solving, adaptability, and sustainability-oriented thinking. The study is expected to reveal a range of learner-initiated innovative behaviors including interdisciplinary thinking, technological adaptability, and eco-centric design perspectives that directly or indirectly align with SDG targets. Findings are anticipated to contribute to theoretical and pedagogical frameworks that encourage the development of innovation-driven sustainability competencies among STEM learners. [2]. Ultimately, this research aims to inform educational practices that empower future professionals to active

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1. Introduction

The increasing urgency of global sustainability challenges has placed education at the forefront of efforts to achieve the United Nations Sustainable Development Goals (SDGs). Across disciplines such as Information and Communication Technology (ICT), Mathematics, Science, and Engineering, learners are expected not only to master technical knowledge but also to develop innovative traits that enable them to generate creative, practical, and sustainable solutions [3,4]. As the world faces complex issues related to climate change, resource management, and technological ethics, fostering innovation-oriented competencies among future professionals has become a critical educational priority [5,6].

While numerous studies have explored the integration of sustainability principles within STEM curricula, much of the current research emphasizes curricular frameworks, instructional design, and policy implementation rather than the learner-driven innovative traits that contribute to sustainability outcomes [7,8]. This reveals a research gap: the lack of understanding regarding how STEM learners personally demonstrate and apply innovation to address sustainability challenges within their fields. The relationship between innovative traits such as creativity, problem-solving, critical thinking, and adaptability and contributions to sustainable development has not been adequately examined at the individual learner level [9,10].

To address this gap, the present study investigates how learners in ICT, Math, Science, and Engineering exhibit and apply innovative traits that are contributory to the SDGs. Grounded in Social Cognitive Theory, the research assumes that individual innovation is shaped by the dynamic interaction among personal characteristics, learning experiences, and environmental contexts. Within this framework, learners' cognitive processes, self-efficacy, and social engagement are seen as central to their ability to create novel solutions that promote sustainability [11].

The study focuses on two core variables: (1) Innovative traits demonstrated by learners, and (2) the application of these traits in addressing sustainability-related challenges. In this study, innovative traits are operationally defined as observable and experience-based learner dispositions manifested through cognitive flexibility, creative problem-solving, adaptive planning, systems-oriented thinking, interdisciplinary integration, and sustainability-oriented decision-making, as expressed in learners' narratives, actions, and reflective accounts within ICT, Mathematics, Science, and Engineering contexts. Key concepts include innovation, sustainability, STEM learning, and the SDGs. Through one-on-one interviews with twenty (n=20) participants from ICT, Math, Science, and Engineering disciplines, the study uses a reflexive thematic analysis approach to uncover how learners conceptualize and enact innovation in relation to sustainability [12].

These dimensions of innovative traits were derived from both established innovation literature and the recurring empirical patterns identified in the participants' accounts. Cognitive flexibility is reflected in learners' ability to shift strategies when solving complex tasks, such as breaking problems into modules or exploring multiple solution paths. Creative problem-solving is demonstrated through the generation of original outputs, including unique programming features, alternative mathematical solutions, and novel design configurations. Adaptive planning emerges in learners' use of sketches, staged experimentation, and iterative refinement. Systems-oriented thinking is evident in modular design approaches and long-term impact considerations, while interdisciplinary integration appears in the blending of concepts from ICT, mathematics, science, and engineering to address sustainability challenges. Sustainability-oriented decision-making is reflected in choices that prioritize resource efficiency, long-term environmental impact, and responsible innovation.

2. Conceptual/theoretical framework

The conceptual framework for "Harnessing Innovative Traits of ICT, Math, Science, and Engineering Learners Contributory to Sustainable Development Goals" is based on integrated 21st-century skills and the principles of sustainable development. This framework postulates that innovative traits, such as creativity, critical thinking, problem-solving, and technological literacy, combined with knowledge in ICT, mathematics, science, and engineering, enable learners to utilize this platform for solving complex global problems [13]. It underlines the importance of fostering an enabling environment for the development of these traits through inter-discipline learning, hands-on experiences, and real-world problem solving, thereby aligning educative outcomes with the SDGs. It also recognizes the role of technological advancements and innovation as mediators that empower learners toward the development of sustainable solutions, hence contributing much to social development and environmental care.

The CURSEA learning framework is underpinned by theories of experiential learning and innovation diffusion, among others [14]. Experiential learning places great importance on the active participation of learners in accomplishing concrete tasks that will enable learners to develop capacities for creating ideas that can be used in SDGs. The constructivist theory explains that learners develop their understanding through valuable experiences and reflection, thus developing an increased interest in issues related to sustainability (15). Innovation diffusion theory describes how the adoption and spreads of innovative attributes among learners will quicken sustainable practices across society and industry (16). Together, these suggest a basis on which appropriate educational strategies can be designed to develop in learners those traits that will lead them to effectively contribute to sustainable development through their knowledge of ICT, math, science, and engineering [17].

Taken together, these disciplinary thinking modes form an integrated theoretical model of interdisciplinary innovative traits, wherein innovation emerges through the interaction of computational, analytical, empirical, and design-oriented cognition. Interdisciplinary collaboration enables learners to transcend disciplinary boundaries, allowing innovative traits to be transferred, recombined, and amplified in addressing complex sustainability challenges [18]. This model provides a theoretical basis for understanding how interdisciplinary STEM education supports collaborative innovation and strengthens learners' capacity to contribute meaningfully to sustainable development goals.

3. Methodology

3.1. Research design

This study employed an exploratory qualitative research design to investigate how learners in ICT, Mathematics, Science, and Engineering demonstrate and apply innovative traits that contribute to the achievement of the United Nations' Sustainable Development Goals (SDGs) [19]. The exploratory approach was chosen to allow for an in-depth understanding of learners' perspectives, behaviors, and experiences in cultivating and utilizing innovation within their academic and practical contexts. This design is appropriate for uncovering patterns, meanings, and contextual nuances that quantitative methods might overlook. While the present study adopts a cross-sectional exploratory qualitative design, it captures innovation as it is enacted within learners' current academic and experiential contexts rather than as a static trait [20]. Participants' narratives consistently referenced repeated practices, iterative learning processes, and sustained application of innovative approaches across multiple tasks and projects, indicating patterns of stability rather than isolated behaviors. These recurring accounts provide evidence of continuity in innovative traits as embedded dispositions shaped by ongoing educational exposure and practice

3.2. Population and sampling

The study involved twenty [20] participants enrolled in undergraduate programs in Information and Communication Technology (ICT), Mathematics, Science, and Engineering programs [21]. Participants were within the typical tertiary education age range, primarily between late adolescence and early adulthood, and were actively engaged in discipline-specific coursework requiring problem-solving, design, experimentation, or system development. [22].

All participants had prior exposure to sustainability-related concepts through formal instruction, project-based learning, or contextual discussions embedded within their respective programs. Such exposure included topics related to resource efficiency, environmental impact, ethical technology use, and long-term system sustainability [23]. However, participants varied in the depth and formality of their sustainability knowledge, reflecting differences in disciplinary emphasis and learning experiences. This variation allowed the study to capture diverse perceptions of how innovative traits are understood and applied within sustainability contexts. Purposive sampling was employed to intentionally select participants who had direct experience with innovation-oriented academic tasks, sustainability-related projects, or problem-solving activities within their disciplines [24]. Selection criteria included active enrollment in ICT, Mathematics, Science, or Engineering programs and demonstrated engagement in coursework or projects involving system design, experimentation, modeling, or technological application. This approach ensured that participants could provide rich, experience-based accounts relevant to the study's objectives.

3.3. Instrument

The interview guide consisted of open-ended questions underwent expert validation by faculty members with backgrounds in STEM education, qualitative research, and sustainability studies to ensure clarity, content relevance, and conceptual alignment with the study's objectives. [25] To strengthen reliability and credibility, the questions were reviewed for internal coherence across objectives and refined to ensure consistent elicitation of innovation-related behaviors across disciplines. Trustworthiness of the measurement was further enhanced through methodological triangulation, which involved cross-verifying interview responses across participants from different disciplines, comparing patterns across questions, and aligning emergent themes with documented learner practices and sustainability-related actions. This triangulated approach supported the consistency and dependability of the findings. Table 1 presents the list of guide questions used by this research study.

Table 1. Interview guide questions.

Objectives	Interview question
1.To identify the innovative traits ICT, Math, Science, and Engineering learners demonstrate in relation to sustainable development goals.	1. What distinctive approaches do you usually adopt when facing complex tasks in ICT, Math, Science, or Engineering? 2. In what situations have your approaches resulted in original outputs? 3. How do these approaches relate to issues connected with sustainability in your discipline?
2. To examine the ways learners, apply innovative traits in ICT, Math, Science, and Engineering contexts to address sustainable development goals.	1. What kinds of sustainability-related challenges have you encountered in your field? 2. How did you respond to sustainability-related challenges through your experiences? 3. What features of your actions in addressing sustainability-related challenges show your contribution to your field?

3.4. Data gathering procedure

Data were collected through one-on-one semi-structured interviews, which provided the flexibility to explore participants' experiences in depth while maintaining alignment with the research objectives [26]. The interview process was guided by an instrument designed to address the two main objectives of the study: first, to identify the innovative traits that learners demonstrate in relation to the Sustainable Development Goals (SDGs); and second, to examine how these traits are applied to address sustainability challenges within the contexts of ICT, Mathematics, Science, and Engineering [27]. Each interview session lasted approximately 30 to 45 minutes and was conducted either in person or through a secure online platform, depending on participant availability and preference. Prior to the interviews, participants were informed about the study's purpose and procedures, and their consent was obtained for audio recording. All interviews were subsequently transcribed verbatim to ensure the accuracy and reliability of data for analysis.

3.5. Data analysis

The collected data were analyzed using Reflexive Thematic Analysis (RTA), following the framework proposed by **Braun and Clarke [28].** This analytical approach involved a systematic and iterative process that allowed for a rich interpretation of the data. The analysis began with familiarization, during which the researcher repeatedly read the interview transcripts to gain a deep understanding of the content and context. This was followed by the generation of initial codes that captured meaningful features related to innovation and sustainability. These codes served as the foundation for identifying and reviewing emerging themes that represented learners' innovative traits and their application to sustainability challenges. The themes were then refined and defined to ensure coherence, consistency, and interpretive depth across the dataset. To enhance analytic rigor and dependability, theme development involved repeated comparison across participant accounts and disciplinary groups to ensure consistency of interpretation. An audit trail was maintained through systematic documentation of coding decisions, theme revisions, and analytical reflections. Reflexive memoing was employed throughout the analysis to surface and manage researcher assumptions, thereby strengthening conformability and ensuring that interpretations remained grounded in participants' narratives. The Sustainable Development Goals (SDGs) were used as an analytical reference point rather than a prescriptive coding framework. Learners' innovative traits and actions were examined in relation to how they implicitly or explicitly aligned with sustainability principles embedded in selected SDGs, such as resource efficiency, long-term impact, environmental responsibility, and systems sustainability. This alignment allowed the analysis to interpret innovation not merely as technical novelty, but as contributory behavior toward sustainable development outcomes

4. Results and discussion

Research Objectives 1. To identify the innovative traits ICT, Math, Science, and Engineering learners demonstrate in relation to sustainable development goals.

Question No. 1. What distinctive approaches do you usually adopt when facing complex tasks in ICT, Math, Science, or Engineering?

1.1 *Breaking it down into smaller modules or tasks*

Ten (10) respondents expressed that when they face a complicated programming task, they break it down into smaller modules so it doesn't feel too overwhelming. They usually list all the features they need to work on and start with the easiest or most familiar part first, just to build momentum. They also make a simple version before adding the more complicated features, so they already have something working even if it's not complete yet. Additionally, they mentioned that they use comments or to-do notes in their code and sometimes separate the functions into different files just to stay organized. They also set small deadlines for each part, so they can track their progress step by step. If they get stuck on one part, they just move to another task for a while so they don't lose motivation or waste too much time being stuck.

> "When I face a complicated programming task, I break it down into smaller modules so it doesn't feel too overwhelming."

> "I use comments or to-do notes in my code and sometimes separate the functions into different files just to stay organized."

1.2 *Approaching complex experiments step by step*

Five (5) respondents shared that they approach a complex experiment. They treat it like following a recipe. First, they read the whole procedure so they know the goal and the steps so nothing surprises them midway. They break the procedure into clear stages and only move to the next stage once they understand and finish the current one. Additionally, they mentioned that if a step fails, they don't panic. Instead, they check their notes, repeat the step, and change only one variable at a time so they can tell what caused the change. When they are unsure about a step, they look for similar experiments, ask a classmate or teacher, or search for a quick video demo but they always try to understand the reason behind each step instead of just copying it. Finally, they summarize results and lessons after finishing so the next time the experiment goes faster and with fewer mistakes.

> "I approach a complex experiment. I treat it like following a recipe. First I read the whole procedure so I know the goal and the steps so nothing surprises me midway."

> "If a step fails, I don't panic: I check my notes, repeat the step, and change only one variable at a time so I can tell what caused the change. "

1.3 Starting with a clear plan

Five (5) respondents expressed that they always start with a clear plan or sketch, especially when it comes to design problems. Visualization really helps them see the bigger picture and spot possible issues early. Before touching any tools or building anything, they make rough sketches or diagrams so they can map out the flow, structure, and function of the design. They also list down the materials or components they might need, so they can estimate costs and resources. Additionally, they shared that when they sketch things out, they can easily adjust or erase parts if they see something that won't work because it's way easier to fix it on paper or a tablet than after building it. They also use these sketches to explore different design options before settling on one. Once they're confident, they move on to more detailed drawings or digital models to check measurements, safety, and functionality.

> "I always start with a clear plan or sketch, especially when it comes to design problems. Visualization really helps me see the bigger picture and spot possible issues early."

> "When I sketch things out, I can easily adjust or erase parts if I see something that won't work because it's way easier to fix it on paper or a tablet than after building it."

Question No. 2. In what situations have your approaches resulted in original outputs?

2.1 *During a programming challenge*

Five (5) respondents expressed that during a programming challenge, they broke the task into smaller modules so they could work on them one by one. Once they finished the main requirements, they used the extra time to add bonus features like user-friendly interfaces and animations. It made their output more polished compared to others. Additionally, they mentioned that they also treated the project like a real system by separating the logic, design, and user interaction modules. This allowed them to include extra functions such as dark mode, customizable settings, and even a performance tracker. Because of this approach, their output didn't just meet the requirements; it stood out as more efficient, flexible, and creative compared to others.

> *"During a programming challenge, I broke the task into smaller modules so I could work on them one by one."*

> *"I also treated the project like a real system by separating the logic, design, and user interaction modules."*

2.2 *When solving math problems*

Ten (10) respondents expressed that when solving problems, they don't immediately use the formula given by the teacher. They try to analyze the problem first and look for patterns or shortcuts. They compare multiple strategies to see which one works best. By doing that, they often discover a cleaner or shorter way to solve a problem than the standard solution. Additionally, they mentioned that they've realized that math problems can be solved in multiple ways, and exploring those paths allows them to be more flexible and creative. That's why instead of memorizing steps; they focus on understanding the concept behind the problem. That allows them to come up with their own way of solving it, especially for word problems or real-life applications.

> "When solving problems, I don't immediately use the formula given by the teacher. I try to analyze the problem first and look for patterns or shortcuts. "

> "I've realized that math problems can be solved in multiple ways, and exploring those paths allows me to be more flexible and creative."

2.3 Designing structures and models

Five (5) respondents mentioned that when designing structures, they like to sketch several drafts first and explore different angles then mix the concepts they've learned from different fields like architecture, physics, and technology to make their design more functional and creative. This helps them visualize how each part connects and identify which design works best. Additionally, they mentioned that by experimenting with styles and materials early on, they can refine both stability and aesthetics. They always push themselves to go beyond what's expected. So, this process allows them to present a design that's not only well thought out but also unique and innovative, which is why their output during the project review stood out.

> "When designing structures, I like to sketch several drafts first and explore different angles then mix the concepts I've learned from different fields like architecture, physics, and technology to make my design more functional and creative."

> "By experimenting with styles and materials early on, I can refine both stability and aesthetics. I always push myself to go beyond what's expected."

Question No. 3. How do these approaches relate to issues connected with sustainability in your discipline?

3.1 *Reduce wasted time and resources*

Ten (10) respondents expressed that in ICT, breaking problems into modules helps reduce wasted time and resources. By dividing a large system into smaller, manageable parts, they can focus on optimizing each module individually. This makes the entire system more efficient, which means it requires less computing power and energy to operate. Additionally, they mentioned that when systems run smoothly and use fewer resources, it reduces the environmental footprint, such as lower electricity consumption and less need for frequent hardware upgrades. This approach aligns with the principles of environmental sustainability because it encourages responsible use of technology and resources.

> *"In ICT, breaking problems into modules helps reduce wasted time and resources. By dividing a large system into smaller, manageable parts, we can focus on optimizing each module individually."*

> *"When systems run smoothly and use fewer resources, it reduces their environmental footprint, such as lower electricity consumption and less need for frequent hardware upgrades."*

3.2 *Understand long-term impacts*

Five (5) respondents expressed that they solve problems by analyzing patterns, which helps them understand long-term impacts. By recognizing trends and relationships between variables, they can make more informed and strategic decisions. This way of thinking is similar to sustainable planning, where anticipating how resources will be used over time is essential. Additionally, they mentioned that this mindset promotes efficient allocation of materials, time, and energy. It also supports the idea of sustainability because it focuses on balance by using what they have wisely today without compromising future needs. Pattern analysis encourages proactive thinking rather than reactive solutions, which is key to building sustainable systems.

> "I solve problems by analyzing patterns, which helps me understand long-term impacts. By recognizing trends and relationships between variables, I can make more informed and strategic decisions."

> "This mindset promotes efficient allocation of materials, time, and energy. It also supports the idea of sustainability because it focuses on balance by using what we have wisely today without compromising future needs. "

3.3 Address complex challenges

Five (5) respondents expressed the need to mix concepts from different fields to design more efficient structures. By combining ideas from various disciplines, they can create solutions that are not only functional but also more sustainable. For example, applying principles from engineering allows them to design structures that use fewer materials, consume less energy, and last longer. Sustainability is all about innovation and integrating different solutions to address complex challenges. Additionally, they also note that when different fields work together, it becomes easier to create systems that adapt to changing conditions and minimize environmental impact. This interdisciplinary approach encourages creativity, resource efficiency, and long-term durability all of which are essential for sustainable development.

> " Mix concepts from different fields to design more efficient structures. By combining ideas from various disciplines, I can create solutions that are not only functional but also more sustainable."

> "When different fields work together, it becomes easier to create systems that adapt to changing conditions and minimize environmental impact."

Research Objectives 2. To examine the ways learners, apply innovative traits in ICT, Math, Science, and Engineering contexts to address sustainable development goals.

Question No. 1. What kinds of sustainability-related challenges have you encountered in your field?

Designing systems that use less energy

Ten (10) respondents expressed that one challenge they face is designing systems that use less energy but still work efficiently. Many solutions are fast but consume too many resources. Sometimes, optimizing performance means sacrificing sustainability, so it's hard to find the right balance. In ICT, they often focus on speed and user experience, but sustainable design also means minimizing energy use, reducing unnecessary processes, and ensuring the system runs smoothly even on low-power devices. Additionally, they mentioned that they've noticed that high-performance solutions usually require more processing power, which increases energy consumption. That's why part of the challenge is optimizing the code and using smarter algorithms that can do more with less. What makes it more difficult is convincing others that sustainable systems are worth the extra effort, since many prefer quick solutions even if they consume more resources in the long run.

> "One challenge I face is designing systems that use less energy but still work efficiently. Many solutions are fast but consume too many resources."

> "I've noticed that high-performance solutions usually require more processing power, which increases energy consumption."

1.2 *Make people understand the value of data-driven decision-making*

Five (5) respondents expressed that they struggle to make people understand the value of data-driven decision-making for long-term sustainability, not just short-term gains. Many still rely on intuition or quick fixes instead of looking at real data and patterns that can help prevent bigger problems in the future. Often, decision-makers focus on immediate results like cost-cutting or speed, without realizing that ignoring data can lead to higher costs and resource waste over time. Additionally, they mentioned that another challenge is making data understandable to those who aren't familiar with technical terms, because if they can't see how numbers translate into real-world impact, they're less likely to support sustainable actions. It's also hard to shift people's mindsets from short-term convenience to long-term responsibility, even when data clearly reveals the consequences of unsustainable choices.

> " We struggle to make people understand the value of data-driven decision-making for long-term sustainability, not just short-term gains."

> "Another challenge is making data understandable to those who aren't familiar with technical terms, because if they can't see how numbers translate into real-world impact, they're less likely to support sustainable actions."

1.3 *High cost of sustainable designs*

Five (5) respondents expressed that designing sustainable structures often costs more at the start, and not everyone sees the long-term benefits. Many stakeholders focus on the initial budget rather than the savings and environmental impact over time. It's challenging to convince clients or decision-makers to invest in sustainable materials and technologies when cheaper, less sustainable options are available. Additionally, they mentioned that sustainable structures often require advanced technology, specialized skills, and high-quality materials, which raise upfront costs. However, these same elements can help reduce maintenance, energy use, and waste in the long run. There's also a lack of awareness about how sustainable structures can contribute to resilience and long-term cost-efficiency, not just environmental protection.

> "Designing sustainable structures often costs more at the start, and not everyone sees the long-term benefits."

> "Sustainable structures often require advanced technology, specialized skills, and high-quality materials, which raise upfront costs."

Question No. 2. How did you respond to sustainability-related challenges through your experiences?

2.1 Focusing on modular design

Five (5) respondents expressed that they focus on modular designs so that systems are easier to maintain and upgrade instead of replacing everything. This approach helps them reduce electronic waste and makes the system more sustainable in the long run. When a certain part becomes outdated or faulty, only that specific module needs to be replaced, allowing the rest of the system to remain functional. Additionally, they mentioned that it also encourages reusability since components can be repurposed or integrated into other projects, minimizing the need for new materials. Aside from being cost-efficient, modular design extends the lifespan of the system and reduces its environmental impact. For them, this is not just a technical strategy but a way of taking responsibility for building systems that support long-term sustainability.

> "I focus on modular designs so that systems are easier to maintain and upgrade instead of replacing everything."

> "t also encourages reusability since components can be repurposed or integrated into other projects, minimizing the need for new materials."

2.2 Modeling real-world problems to predict long terms impact

Five (5) respondents expressed that they respond to sustainability challenges by modeling real-world problems using equations or statistics to predict long-term impacts. This allows them to see patterns and possible outcomes before making decisions, which helps in creating more effective and sustainable solutions. By analyzing data trends, they can identify potential risks, resource shortages, or environmental effects early on. Additionally, they mentioned that it also helps in finding the most efficient ways to allocate resources and minimize waste. Using mathematical models makes the solutions evidence-based rather than relying on guesswork. This way, the strategies developed are not only practical in the short term but also sustainable and beneficial in the long run.

> "I respond to sustainability challenges by modeling real-world problems using equations or statistics to predict long-term impacts. "

> "It also helps in finding the most efficient ways to allocate resources and minimize waste. Using mathematical models makes the solutions evidence-based rather than relying on guesswork."

2.3 Defending the sustainable project

Ten (10) respondents expressed that when faced with budget limits, they defend sustainable solutions by showing their long-term benefits even if the initial cost is higher. They explain that while sustainable options may seem expensive at first, they often lead to lower maintenance costs, reduced energy consumption, and longer system lifespans. They highlight how investing in sustainable solutions can prevent future expenses and environmental damage, which ultimately saves more resources over time. Additionally, they mentioned that they also use data and real-life examples to make the argument more convincing, showing how short-term sacrifices can lead to long-term gains. For them, sustainability is not just about the present but it's about making smart choices that benefit both people and the environment in the future.

> "When faced with budget limits, I defend sustainable solutions by showing their long-term benefits even if the initial cost is higher. "

> "I also use data and real-life examples to make the argument more convincing, showing how short-term sacrifices can lead to long-term gains. "

Question No. 3. What features of your actions in addressing sustainability-related challenges show your contribution to your field?

3.1 Designing systems with modular structures

Ten (10) respondents expressed that they design systems with modular structures so that parts can be updated without replacing everything. This reduces electronic waste and energy use while making maintenance more efficient. By allowing easy upgrades, they help extend the system's lifespan and support sustainable innovation. Additionally, they mentioned that teams can integrate new technologies without redesigning the entire system, which saves time, costs, and resources. They see modular design as a way to make technology more future-proof, ensuring that solutions remain adaptable and environmentally responsible over time. This is their way of contributing to sustainability in the ICT field.

> "I design systems with modular structures so that parts can be updated without replacing everything."

> "Teams can integrate new technologies without redesigning the entire system, which saves time, costs, and resources."

3.2 Applying mathematical modelling

Five (5) respondents shared that they apply mathematical modeling to understand how resources are used over time. This helps create strategies that are both efficient and sustainable by identifying trends, predicting future outcomes, and minimizing waste. Through these models, they can simulate different scenarios and evaluate which solutions will have the most positive long-term impact. Additionally, they mentioned that they use data to guide decisions, making resource management more strategic and evidence-based. This allows decision-makers to rely on data rather than guesswork. By translating real-world problems into mathematical representations, they contribute to developing strategies that balance resource use, cost-effectiveness, and environmental responsibility.

> "I apply mathematical modeling to understand how resources are used over time. This helps create strategies that are both efficient and sustainable by identifying trends, predicting future outcomes, and minimizing waste."

> "I use data to guide decisions, making resource management more strategic and evidence-based."

3.3 Designing structures that use eco-friendly

Five (5) respondents mentioned that they design structures that use eco-friendly and durable materials, reducing the need for frequent repairs or replacements. By choosing sustainable materials, they help lower the overall environmental impact of construction and ensure that structures last longer with minimal maintenance. This approach not only conserves resources but also lowers costs over time. Additionally, they shared that they also consider how these materials interact with their surroundings, ensuring energy efficiency and resilience against environmental factors. By integrating sustainability into the design phase, they contribute to creating structures that are functional, cost-effective, and environmentally responsible.

> "I design structures that use eco-friendly and durable materials, reducing the need for frequent repairs or replacements."

> "I also consider how these materials interact with their surroundings, ensuring energy efficiency and resilience against environmental factors."

5. Discussion

Innovative Traits Demonstrated by ICT, Math, Science, and Engineering Learners in Relation to Sustainable Development Goals. Findings from the interviews revealed that the interviewed participants from ICT, Mathematics, Science, and Engineering articulated a range of innovative traits as they reflected on their own academic and project-based experiences. Rather than representing all learners within these disciplines, the findings reflect how the participating respondents perceived, described, and enacted innovation within sustainability-related contexts. Across narratives, participants consistently emphasized creative problem-solving, adaptive thinking, systems-oriented reasoning, and iterative planning as strategies they personally employed when addressing complex academic and sustainability-oriented challenges [29]. These traits emerged from participants' accounts as situated practices, shaped by disciplinary demands, learning environments, and individual experiences rather than as universal characteristics of all learners.

Participants from ICT programs described how they applied design thinking and computational creativity in developing applications aimed at improving efficiency and reducing unnecessary resource use. Mathematics participants highlighted analytical innovation through the construction of alternative solution paths and models that enabled more efficient interpretation of data and resource allocation [30]. Participants from Science programs linked their innovative practices to systematic experimentation, evidence-based reasoning, and reflective analysis, particularly in sustainability-related laboratory and field tasks [31]. Engineering participants emphasized iterative design, prototyping, and materials consideration as part of their efforts to balance functionality, efficiency, and long-term impact.

These findings suggest that innovation among learners is not limited to technical expertise but extends to a mindset of sustainability-oriented creativity [32]. Their ability to integrate ethical awareness and global responsibility into technical and analytical thinking underscores the potential of education in these fields to cultivate agents of sustainable change. [33].

Application of Innovative Traits in Addressing Sustainability-Related Challenges. When asked how they apply innovative traits to sustainability challenges, participants described a range of practices demonstrating the integration of theory and action. A recurring theme was the translation of innovative ideas into real-world applications that align with specific SDGs, such as affordable clean energy (SDG 7), sustainable cities and communities (SDG 11), and responsible consumption and production (SDG 12).

ICT learners shared experiences in developing software solutions that monitor energy usage or track carbon footprints [34)]. Math students described contributing through the development of predictive models for climate patterns or optimization algorithms for resource management. Science learners often engaged in laboratory and community-based initiatives such as water purification experiments or renewable material development that demonstrate innovation rooted in sustainability. Engineering students focused on tangible problem-solving through design and prototyping, emphasizing energy-efficient mechanisms, waste management systems, and sustainable construction methods.

A strong pattern across all disciplines was the integration of collaboration and interdisciplinary. Learners recognized that sustainability challenges require collective effort, prompting them to work with peers from different fields. This collaboration enabled the merging of computational, analytical, and technical innovations, leading to holistic solutions. Moreover, learners often expressed that their engagement with sustainability issues fostered reflective and ethical innovation they began to consider not only efficiency and performance but also environmental impact, accessibility, and long-term social implications.

The discussion highlights that learners in ICT, Math, Science, and Engineering embody a shared innovative spirit characterized by creativity, adaptability, and ethical awareness. These traits are actively harnessed to address sustainability challenges, demonstrating the transformative role of STEM-related education in advancing SDGs. [35]

Educationally, these findings suggest that curricula should continue to emphasize experiential and project-based learning that situates innovation within real-world sustainability contexts. Encouraging reflexivity, interdisciplinary collaboration, and problem-based inquiry can further strengthen learners' capacity to act as innovators for sustainable development.

In summary, ICT, Math, Science, and Engineering learners are not merely acquiring technical knowledge they are developing innovation-driven mindsets that enable them to contribute meaningfully to sustainability goals. Their experiences illustrate how higher education can cultivate globally responsive innovators capable of designing creative, inclusive, and sustainable solutions for the future. The study advances theory by articulating how discipline-specific thinking modes interact to shape differentiated yet integrative innovative traits among STEM learners. Linking disciplinary epistemic cultures with sustainability-oriented innovation, the study extends existing innovation and sustainability frameworks and offers a conceptual basis for interdisciplinary collaboration in education for sustainable development

6. Conclusion

The findings indicate that the interviewed ICT, Math, Science, and Engineering participants demonstrated innovative traits through their described approaches to problem-solving, planning, experimentation, and sustainability-oriented decision-making within their academic contexts. Learners commonly exhibit creativity, strategic thinking, and problem-solving skills through approaches such as breaking complex tasks into manageable parts, systematic experimentation, and careful planning. These strategies not only foster originality in outputs such as efficient programs, unique designs, and creative mathematical solutions but also promote resource efficiency and sustainability awareness. When addressing sustainability challenges, learners actively apply these traits by designing modular systems, using data-driven and mathematical models, and advocating for sustainable solutions despite practical constraints like cost or limited awareness. Their actions reflect a growing commitment to long-term impact, resource conservation, and interdisciplinary collaboration. Overall, the findings highlight that learners in STEM fields are not only innovators but also responsible problem-solvers who integrate sustainability into their academic and practical pursuits. Their innovative mindsets demonstrate how education in ICT, Math, Science, and Engineering can cultivate future professionals capable of creating solutions that are both technologically advanced and environmentally sustainable. Despite these contributions, the study is limited by its cross-sectional qualitative design, which captures innovative traits as enacted within a specific academic period rather than across extended developmental trajectories. As such, the findings reflect demonstrated patterns of innovation at a particular point in learners' educational experiences, without claiming permanence or causal stability over time.

7. Recommendations

Future research may extend the present findings through longitudinal tracking of selected learners over a 6–12-month period to examine the stability, evolution, and sustainability of innovative traits across academic stages and applied contexts. Repeated data collection points may document changes in innovative behaviors, sustainability-oriented practices, and disciplinary integration as learners engage in advanced coursework, internships, or community-based projects. Such longitudinal designs would enable stronger causal inferences regarding the role of educational interventions and experiential learning in sustaining innovation for sustainable development.

Accordingly, harnessing the innovative traits of learners in this field will require prioritizing interdisciplinary and experiential learning approaches within educational institutions and policy frameworks. The support for project-based, problem-solving activities relevant to the challenges faced by society will increase students' creativity, critical thinking, and ability to collaborate. Furthermore, an environment of curiosity, adaptability, and technological mastery will better equip them to answer the call of SDGs. This calls for investment in state-of-the-art infrastructure, digitization, and teacher development to ultimately prepare the necessary skills and mindset in learners for innovative thinking toward sustainable problem-solving.

Strong partnerships between education institutions, industry, government, and communities are important for furthering opportunities in which learners apply skills in practical contexts. Mentorship programs, innovation hubs, and research initiatives can also provide avenues for students to develop solutions to address SDGs on clean energy, quality education, and sustainable cities. Encouraging participation in global challenges, competitions, and collaborative projects will spur learners to become active contributors towards sustainable development, developing a generation of innovative thinkers in service of a truly sustainable and equitable future.

Conflict of interest

The authors declare no conflict of interest

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