International Journal of Ethnoscience and Technology in Education (IJETE)
https://e-journal.undikma.ac.id/index.php/ijete/index

March 2024 Vol. 1, No. 1
pp. 28-41

Science Learning in the Context of 'Indigenous Knowledge' for Sustainable Development

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Article Info

Article History
Received: February 2024
Revised: February 2024
Published: March 2024

Keywords
Indigenous knowledge;
Science education;
Sustainable development;
Interdisciplinary learning;
Cognitive development.

10.33394/ijete.v1i1.10880

Abstract

This study investigates the integration of Indigenous Knowledge (IK) into science education as a means to foster sustainable development among high school students. Through a qualitative descriptive approach, involving semi-structured interviews with 20 participants in Morocco, the research explores the impact of IK on enhancing students' understanding of local ecosystems, promoting interest in interdisciplinary studies, and contributing to cognitive and personal growth towards sustainable thinking. Findings indicate that incorporating IK into science curricula significantly enriches students' learning experiences by bridging the gap between traditional wisdom and scientific inquiry, thus making science education more relevant and engaging. This approach not only deepens students' appreciation for cultural diversity and environmental stewardship but also encourages a more holistic understanding of science and its application to global challenges such as climate change and biodiversity conservation. The study highlights the educational value of integrating IK in developing thinking and problem-solving skills, and a sense of global citizenship among students. It advocates for educational reforms that include IK as a vital component of science learning, suggesting that such integration can play a crucial role in achieving sustainable development goals by preparing students to engage thoughtfully with complex environmental and societal issues. This research contributes to the discourse on enhancing science education through the inclusion of diverse knowledge systems, offering insights into how such pedagogical innovations can support more sustainable and inclusive futures.

How to Cite: Yazidi, R. E., & Rijal, K. (2024). Science Learning in the Context of 'Indigenous Knowledge' for Sustainable Development. *International Journal of Ethnoscience and Technology in Education, 1*(1), 28-41. doi:https://doi.org/10.33394/ijete.v1i1.10880

INTRODUCTION

Education serves as a crucial conduit for developing quality, competent individuals equipped with insights, skills, and knowledge, thereby fostering personal growth and talent development (Darling-Hammond et al., 2020). It aims to empower individuals to navigate the

evolving landscape shaped by scientific and technological progress, highlighting the imperative for addressing educational challenges in both quality and quantity (Gurova et al., 2015). The pivotal role of science education within this framework is underscored by its alignment with societal progression and the concerns over diminishing science achievement and engagement levels (LaForce et al., 2017).

A significant issue within science education is the students' perception of secondary science classes as uninteresting, unengaging, and irrelevant (Anderhag et al., 2016; Potvin & Hasni, 2014), echoing sentiments that science learning lacks relevance from the students' perspective, contributing to its unpopularity (Rundgren & Rundgren, 2015). The disconnection between science teaching and students' daily lives and societal contexts has been identified as a key reason for this perception gap (Childs et al., 2015). Emphasizing the importance of science education in preparing students for thoughtful, critical, and creative engagement with societal issues stemming from scientific and technological impacts is essential (Sjöström & Eilks, 2018; Sjöström, 2013; Stuckey et al., 2013).

Enhancing the relevance of science education necessitates innovative curriculum and pedagogical approaches that transcend traditional science theory and fact learning (Eilks & Hofstein, 2015). Incorporating everyday life and societal contexts into science learning can help students recognize the significance of science (Østergaard, 2017). Efforts to innovate in science education and learning should be grounded in theory and evidence, including the integration of 'Indigenous Knowledge' to enrich science learning practices (Zidny et al., 2020).

The effectiveness of science education is reflected in its capacity to inspire curiosity, open-mindedness, and analytical thinking among students (Bayani et al., 2023). It is vital for students to perceive science not merely as an academic exercise but as a lens through which to understand their world (Ramma et al., 2018). Despite the intellectual challenges posed by science, which often result in student difficulties and disengagement (Bayani et al., 2023), addressing motivational and enthusiasm barriers is crucial for improving learning outcomes (Macho-Stadler and Elejalde-García, 2013). Mastery in content, pedagogical, and content-pedagogical knowledge plays a significant role in knowledge acquisition, emphasizing cognitive, affective, and motivational domains (Angeli & Valanides 2009; Autio 2011; O'Keefe & Linnenbrink-Garcia 2014). Integrating technology with these knowledge aspects has been shown to enhance learning outcomes (Ramma, Samy, & Gopee 2015). Effective pedagogical strategies, such as exploratory learning models, are essential for facilitating knowledge transfer and achieving learning goals (Arends, 2012), with research indicating that inquiry-based exploratory learning enhances higher-order thinking skills (Azizmalayeri et al., 2012; Cleovoulou & Beach, 2019; Duran & Dökme, 2016), and is particularly impactful when connected to Indigenous Knowledge contexts (Zidny et al., 2020, 2020, 2023).

Referring to study interests in recent years, there has been a growing recognition of the importance of integrating Indigenous knowledge with formal scientific education. This integration is seen as a pathway to enrich the learning experience, making it more relevant and comprehensive for students across diverse cultural backgrounds. Indigenous knowledge

systems encompass a broad spectrum of understanding about the natural world, developed through generations of close interaction with the environment. These systems offer unique insights into sustainability, ecology, and the intricate balances within nature, which are often overlooked in conventional science education. However, the integration of Indigenous Knowledge into mainstream science education poses certain challenges. These include pedagogical adjustments, curriculum development, and the need for educators who are adept at navigating both knowledge systems.

By creating a learning environment that respects and incorporates Indigenous Knowledge, educators can cultivate a more inclusive and comprehensive approach to science education. This not only enhances students' cognitive development and learning outcomes but also prepares them for the complexities of addressing global challenges such as climate change and biodiversity conservation, making a compelling case for the vital role of Indigenous Knowledge in fostering sustainable development.

The current study aims to explore the impact of science learning in the context of Indigenous Knowledge for students' sustainable development. The research questions are as follows.

1. How does exposure to Indigenous Knowledge within science education enhance students' understanding of local ecosystems and traditional environmental practices?
2. What effect does integrating Indigenous Knowledge into science curricula have on students' interest in interdisciplinary studies combining science with traditional wisdom?
3. How does the inclusion of Indigenous Knowledge in science education contribute to students' cognitive development and personal growth towards sustainable thinking?
4. In what ways do science learning experiences enriched with Indigenous Knowledge foster meaningful engagement and insight into sustainability among students?
5. How does learning science in the context of Indigenous Knowledge influence students' advocacy for the preservation of indigenous practices and integration into sustainable development strategies?

METHOD

General Background of the Research

This study is framed as qualitative descriptive research (Wong & Kowitlawakul, 2020), focusing on the integration of 'Indigenous Knowledge' within the realm of science learning. By implementing a learning intervention that incorporates Indigenous Knowledge into science education, the research seeks to understand the nuanced impacts on students' learning outcomes, attitudes, and conceptual understandings. The methodological approach is designed to capture the depth and complexity of students' experiences and perceptions through semi-structured interviews, offering rich insights into the cognitive processes influenced by this learning method.

The choice of qualitative methodology is pivotal to the study's objectives, allowing for an in-depth exploration of the subjective experiences and cognitive developments of students engaged in science learning that emphasizes Indigenous Knowledge. This approach facilitates

a nuanced understanding of the educational impact of Indigenous Knowledge, providing a detailed picture of how such content can enrich science education.

Participant

The study utilized convenience sampling to select its participants, comprising 20 high school students from Morocco. These students were engaged in a three-month educational intervention that focused on science learning through the lens of 'Indigenous Knowledge.' The rationale behind the sample size is grounded in the principle of data saturation in qualitative research, as outlined by Priest (2006), which suggests that the sample size should be determined by the point at which no new information is obtained. Data saturation was achieved after interviews with 17 participants, with three additional participants subsequently included to confirm the saturation point. This careful consideration in participant selection ensured a comprehensive understanding of the research phenomena, making the study's findings robust and reflective of the targeted student population's experiences.

Data Collection and Ethical Considerations

The research employed a carefully developed and expert-validated interview guide to facilitate semi-structured interviews. This instrument was designed to elicit detailed responses about students' learning outcomes, attitudes, and conceptual understandings development within the context of 'Indigenous Knowledge' in science learning. The questions aimed to uncover students' understanding of Indigenous Knowledge, their interest in learning about Indigenous issues, the outcomes of such learning experiences, and their perceptions of the significance and integration of Indigenous Knowledge with scientific principles. Expert validation confirmed the content and construct validity of the interview guide, ensuring its appropriateness for the research objectives.

Data collection spanned from August to October 2023, with each participant providing written informed consent prior to engagement. Interviews, lasting between 20 to 40 minutes, were audio-recorded to accurately capture students' responses. Additional qualitative data, including field notes on participants' non-verbal cues, were meticulously recorded to enrich the data's depth and assist in interpreting the findings. Ethical approval was secured from the university ethics review committee, and the research protocol was approved by the participating school, ensuring adherence to ethical standards in research involving human subjects. This thorough ethical consideration underscores the commitment to respecting participants' rights and integrity throughout the research process.

Data Analysis

Following data collection, interviews were transcribed verbatim to facilitate comprehensive data analysis. The analysis was guided by Braun and Clarke's (2006) thematic analysis framework, allowing for a systematic examination of the data to identify and interpret patterns of meaning. Initial coding was performed independently by two

researchers, who meticulously reviewed each transcript to highlight significant statements and organize these into preliminary codes. These codes were then collaboratively reviewed and refined, facilitating the identification of recurrent ideas that were organized into subthemes and overarching themes. This iterative process ensured a rigorous and reflective engagement with the data, enabling a detailed thematic exploration of students' cognitive development in the context of Indigenous Knowledge integration.

Trustworthiness

The study's methodological rigor is underscored by adherence to Lincoln and Guba's (1985) criteria for evaluating the trustworthiness of qualitative research: credibility, dependability, confirmability, and transferability. Credibility was enhanced through the use of audio recordings and field notes, complemented by member checking procedures that allowed participants to review and potentially revise their interview transcripts. Dependability was established through a transparent documentation of the research process, from objectives and design to data collection and analysis strategies. Confirmability was achieved through a collaborative analysis process, mitigating potential researcher bias and ensuring that findings accurately reflect participants' experiences. Transferability was supported by the careful selection of a representative sample and achieving data saturation, indicating that the study's findings are true.

RESULTS AND DISCUSSION

The interview with the student participating in the science learning program that integrates Indigenous Knowledge provides insightful findings on the impact of on students' learning outcomes, attitudes, and conceptual understandings. These findings can be discussed across several key themes: enhanced understanding of 'Indigenous Knowledge', increased interest in interdisciplinary learning, cognitive and personal growth, meaningful learning experiences, and advocacy for integration and preservation.

- ***Enhanced understanding of 'Indigenous Knowledge'***

Interviewer:
Let's start with your understanding of the Indigenous Knowledge context. Can you share how familiar you are with this topic?
Student (S-07):

> *"…before this program, my knowledge of Indigenous Knowledge was quite basic. I knew it involved traditional practices and understandings passed down through generations, but I hadn't deeply explored how it connected with formal science learning. This program has significantly expanded my understanding, highlighting the depth and relevance of Indigenous Knowledge to contemporary environmental and scientific challenges."*

The student's initial limited awareness of Indigenous Knowledge was significantly broadened through their participation in the program. This highlights the educational value of integrating Indigenous perspectives into science curricula, not only in terms of imparting

knowledge but also in fostering a deeper appreciation for diverse ways of understanding the world. The program served as a bridge, connecting students with the rich wisdom and environmental stewardship inherent in Indigenous cultures, which is often overlooked in conventional science education.

The profound expansion of students' awareness and understanding of Indigenous Knowledge through the program underscores the transformative potential of integrating these perspectives into science curriculum. This approach not only enriches the academic content but also bridges cultural divides, fostering a comprehensive appreciation for the depth and relevance of Indigenous wisdom in addressing contemporary environmental and scientific challenges (Jessen et al., 2022). The student's reflections reveal how such educational experiences can dismantle preconceived notions about Indigenous Knowledge, highlighting its sophistication, relevance, and applicability to modern scientific inquiries. By weaving Indigenous perspectives into the fabric of science education, students are offered a more rounded and inclusive view of knowledge, which is crucial in a world that increasingly values diversity and interconnectedness (Snively & Corsiglia, 2001).

The value of this enhanced understanding extends beyond academic achievement; it cultivates empathy, respect, and a genuine interest in the contributions of Indigenous cultures to global knowledge. This shift in perspective is essential for developing a generation of learners who are not only scientifically literate but also culturally sensitive and aware of the importance of sustaining the planet's biodiversity and cultural heritage. Such education prepares students to engage with complex global issues, such as climate change and biodiversity loss, through a lens that values and utilizes the insights of Indigenous Knowledge alongside scientific research (Brubacher et al., 2024). This holistic approach to learning is indicative of an educational paradigm that recognizes the importance of diverse knowledge systems in fostering sustainable development and environmental stewardship (Ullah et al., 2023).

- ***Increased interest in interdisciplinary learning***

Interviewer:

Are you interested in taking part in science learning that incorporates Indigenous Knowledge issues? And if so, why?

Student (S-11):

> *"…yes, I am very interested. My reason for this interest stems from the recognition that Indigenous Knowledge offers a unique perspective on sustainability and environmental stewardship. I believe integrating this with formal science education enriches our learning experience, making it more holistic and grounded in real-world contexts. It's a way to bridge the gap between traditional wisdom and scientific innovation, which I find incredibly valuable for addressing global challenges."*

The student's expressed enthusiasm for the interdisciplinary nature of the program, blending Indigenous Knowledge with scientific learning, reflects a broader educational imperative to prepare students for the complexities of the modern world. Interdisciplinary

learning that incorporates Indigenous perspectives not only breaks down the silos of traditional subject areas but also encourages students to think critically and creatively about how different types of knowledge can complement and enhance each other. This approach fosters a learning environment where students are more engaged and invested in their education, seeing it as directly relevant to real-world issues and challenges. The student's interest highlights the effectiveness of this approach in increasing motivation and curiosity, key drivers of deep and meaningful learning.

Furthermore, the interdisciplinary methodology promotes a more nuanced understanding of global challenges, equipping students with the tools to approach problems from multiple angles and develop innovative solutions that draw on a diverse range of knowledge sources. This educational strategy emphasizes the value of integrating Indigenous Knowledge into science learning, not as a supplementary component but as an integral part of understanding complex ecological and social systems (Reyes-García, 2023). The student's response indicates that such learning experiences can inspire a lifelong commitment to interdisciplinary problem-solving and a deeper appreciation for the role of cultural diversity in fostering scientific and environmental innovation. This educational model is crucial for preparing students to navigate and contribute to a world where the interdependence of social, environmental, and scientific issues is increasingly evident (Zidny et al., 2020).

- ***Cognitive and personal growth***

Interviewer:
Can you describe the cognitive learning outcomes you've achieved during this process?
Student (S-15):

> *"…throughout this learning experience, I've developed a deeper thinking ability, particularly in understanding complex ecological relationships and the impact of human actions on the environment. Learning through the lens of Indigenous Knowledge has also enhanced my problem-solving skills, encouraging me to consider multiple perspectives and solutions. Additionally, I've gained a more profound respect for the importance of diversity in knowledge systems and their contributions to scientific understanding and innovation."*

The integration of Indigenous Knowledge into science education has profound implications for students' cognitive and personal growth, as evidenced by the student's experiences. Enhanced thinking and problem-solving skills emerged as significant cognitive outcomes, underscoring the role of Indigenous Knowledge in promoting a more holistic and reflective approach to learning (Forsyth, 2017). The student's ability to critically evaluate ecological relationships and human-environment interactions was notably improved, suggesting that exposure to diverse knowledge systems encourages a deeper, more complex understanding of science and its applications (Chirgwin & Huijser, 2015). This cognitive development is essential for students to effectively engage with and contribute to solving the pressing environmental and social challenges of our time.

On a personal level, the learning process was described as meaningful and transformative, impacting not just the student's academic pursuits but also their values and

worldview. This personal growth reflects the power of education that respects and integrates Indigenous Knowledge, fostering a sense of global citizenship and responsibility towards environmental stewardship and cultural preservation (Jessen et al., 2022). The student's reflection on the transformative nature of the learning experience highlights the potential of such educational approaches to inspire a profound reevaluation of one's relationship with the natural world and diverse cultures. It suggests that when students are exposed to and engage with Indigenous Knowledge, they develop a more compassionate, respectful, and inclusive outlook, which is critical for fostering a more sustainable and equitable global society.

- ***Meaningful learning experiences***

Interviewer:

How meaningful do you find the science learning process in the context of Indigenous Knowledge?

Student (S-017):

> *"…it's been incredibly meaningful. This approach has not only broadened my scientific knowledge but also deepened my appreciation for cultural diversity and the wisdom of Indigenous communities. It has made me more aware of the interconnectedness of all living things and the importance of maintaining a sustainable relationship with our environment. This learning process has been transformative, influencing not just my academic pursuits but my personal values and worldview."*

The learning process was described as meaningful and transformative, impacting the student not just academically but also personally. This underscores the potential of integrating Indigenous Knowledge into science education to create more engaging, relevant, and impactful learning experiences (Zidny et al., 2020, 2020, 2023). By connecting scientific concepts with Indigenous perspectives, students can develop a deeper connection to the material, fostering a greater sense of responsibility towards environmental stewardship and sustainability.

- ***Advocacy for integration and preservation***

Interviewer:

Finally, how do you think you can maintain local wisdom heritage with the scientific knowledge you gain during the learning process?

Student (S-19):

> *"…I believe it's about finding a balance and integrating these knowledge systems in a respectful and meaningful way. By applying scientific knowledge to support and amplify Indigenous practices, we can help preserve local wisdom while also advancing sustainable solutions. It's also important to advocate for the inclusion of Indigenous perspectives in scientific research and policy-making, ensuring these voices are heard and valued. Personally, I plan to continue exploring this integration in my studies and future career, aiming to contribute to a more sustainable and inclusive approach to science and environmental management."*

The student's response also highlights a forward-looking perspective on maintaining and integrating local wisdom with scientific knowledge. This indicates an awareness of the importance of preserving Indigenous Knowledge through respectful and meaningful integration within scientific research and policy-making. The student's commitment to continuing this exploration in their future career suggests that such educational programs can inspire the next generation of scientists and policymakers to value and incorporate Indigenous perspectives in their work (Da Silva et al., 2023).

The student's insights into maintaining and integrating local wisdom with scientific knowledge underscore an important aspect of the educational experience: the advocacy for a respectful and meaningful collaboration between Indigenous Knowledge and scientific inquiry (Alexander et al., 2019). This perspective is crucial for the preservation of Indigenous cultures and their wisdom, emphasizing the need for educational systems to not only recognize but actively incorporate Indigenous perspectives into research and policy-making (Ritchie, 2021). The student's commitment to exploring this integration in their future career reflects a broader recognition of the importance of such knowledge in addressing global environmental and social issues. This proactive stance on advocacy highlights the role of education in preparing students to become champions of a more inclusive and sustainable approach to science and environmental management. Furthermore, the emphasis on collaborative efforts to preserve local wisdom alongside scientific advancements points to a critical pathway for achieving sustainable development goals (Arico, 2023). By valuing and using the insights gained from Indigenous Knowledge, students like the one interviewed can contribute to creating solutions that are culturally sensitive, environmentally sustainable, and scientifically sound.

The findings from the interview suggest that science learning programs integrating Indigenous Knowledge can significantly enhance students' cognitive dimensions, foster a deeper understanding of and respect for Indigenous perspectives, and encourage personal and academic growth. These programs not only enrich students' learning experiences but also prepare them to contribute to a more sustainable, inclusive, and interdisciplinary approach to science and environmental management. This aligns with broader educational goals of fostering thinking skills, problem-solving skills, and an appreciation for cultural diversity and sustainability.

CONCLUSION

The integration of 'Indigenous Knowledge' within science education, as explored in this study, marks a significant step towards redefining educational paradigms to embrace a more inclusive, holistic approach to learning. By embedding Indigenous perspectives into the science curriculum, the research highlights a transformative educational practice that not only enhances students' cognitive development but also fosters a profound respect for cultural diversity and environmental sustainability. The findings suggest that such an approach not only broadens the academic horizons of students but also prepares them to engage with complex global challenges through a lens that values the amalgamation of scientific and

Indigenous knowledge systems. This educational strategy is shown to cultivate thinking and problem-solving skills, and a deeper understanding of the interconnections between human societies and the natural world, thereby equipping students with the competencies necessary for contributing to sustainable development and environmental stewardship.

Furthermore, the study emphasizes the importance of 'Indigenous Knowledge' in enriching science education and promoting a more comprehensive understanding of sustainability issues. The positive feedback from students regarding their engagement and learning outcomes underscores the potential of integrating Indigenous wisdom to make science education more relevant, engaging, and meaningful. This approach not only acknowledges the rich contributions of Indigenous cultures to global knowledge but also challenges the conventional boundaries of science education to include diverse epistemological perspectives. As the world faces unprecedented environmental challenges, the need for an education system that is both inclusive and forward-thinking has never been more critical. The integration of 'Indigenous Knowledge' into science curricula represents a promising pathway towards achieving this goal, fostering a generation of learners who are well-prepared to advocate for and implement sustainable solutions.

LIMITATION

One limitation of this study is its qualitative descriptive nature, focusing on a specific sample of high school students from Morocco, which may limit the generalizability of the findings to other contexts and educational settings. The reliance on self-reported data through semi-structured interviews, while offering deep insights into students' experiences and perceptions, could also introduce subjectivity and bias. Further research incorporating quantitative methods and a broader demographic could provide a more comprehensive understanding of the impact of Indigenous Knowledge integration across different educational landscapes.

RECOMMENDATION

Based on the study's findings, it is recommended that educational policymakers and curriculum developers consider the integration of 'Indigenous Knowledge' into science education as a strategic approach to enhance learning outcomes and foster sustainable development. Schools should provide professional development for teachers to equip them with the skills and knowledge necessary to effectively incorporate 'Indigenous Knowledge' into their teaching practices. Additionally, collaborative partnerships between educational institutions and Indigenous communities could further enrich the curriculum and ensure the respectful and accurate representation of Indigenous perspectives.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Acknowledgment
The authors extend their heartfelt gratitude to the students, educators, and Indigenous community members whose invaluable contributions made this study possible. Their insights and willingness to share their experiences have been instrumental in enriching our understanding of integrating 'Indigenous Knowledge' into science education, paving the way for more inclusive learning environments.

Conflict of interests
The authors declare no conflict of interest.

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