Innovative Integration of Environmental Awareness into Mathematics Education: Insights from Teachers' and Students' Perceptions in Bahawalpur

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Abstract

This research examines the novel incorporation of environmental consciousness into mathematics instruction by examining the viewpoints of teachers and pupils in Bahawalpur. This research examined the effectiveness of interdisciplinary methods in improving environmental understanding and promoting long-term sustainability via mathematical approaches. Information was gathered through an online questionnaire administered to educators and pupils from various public and private educational establishments. The study's findings indicate a positive response to incorporating environmental subjects into mathematics course materials, with both groups acknowledging the value of this integration in fostering critical thinking and problem-solving skills. Significant discrepancies between government and private institutions reveal difficulties accessing resources and providing adequate pedagogical support. Interdisciplinary methods effectively increase environmental awareness, but the research also indicates a requirement for targeted teacher training and curriculum development initiatives. The study's findings culminate in proposals for creating uniform curricula, comprehensive professional development initiatives, and institutional backing to enhance environmental and mathematical education integration across disciplines.

Keywords: Interdisciplinary Education, Environmental Awareness, Mathematics Integration, Pedagogical Strategies, Sustainable Education, Educational Innovation.

Introduction

Over the last couple of decades, education has mainly focused on dealing with global environmental issues. One of the ways that can help a lot in the development of ecological awareness in students is through the use of environmental concepts intermingled within everyday teaching topics such as Mathematics. Mathematics alone as a subject provides skills for data analysis, problem-solving, and the use of models, in particular, in comprehending environmental problems, including global warming, pollution, and resource exhaustion. Mumu et al. (2020) described the learning designs integrating zones into mathematics education and pointed to the issues unique to Papua. Mumu and Tanujaya (2020) also analyzed students' metacognition abilities in solving environmental mathematics problems, identifying three groups of learners: cognitive, deliberate, and meta-cognitive. They not only enhanced specific metacognitive skills but also made environmental awareness ñ. Jianguo (2004) postulated the need to enhance teachers' ecological sensitivity to facilitate environmental integration in mathematics education. All these studies show that integrating mathematics and ecological

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education improves students' achievement in learning content and environment awareness (Özdemir, 2021; Mumu et al., 2020; Mumu & Tanujaya, 2020; Jianguo, 2004). Still, this integration is deemed to support the ecological consciousness of the teachers and students. Literature has documented practical samples of this method, like paper waste analysis in classes to apply mathematics in the learner's sociocultural context (Jianguo, 2004).

Similar studies highlight that cross-cutting mathematics with environmental education at schools has significant advantages. Thus, the interdisciplinary approach improves students' ecological literacy and ensures that the content of lessons is illustrated by real-life examples from mathematics (Özdemir, 2021). Previous studies indicate that integrating these subjects enhances students' knowledge of environmental matters and their part in addressing them (Özdemir, 2021). There are several ways to combine, for example, the analysis of air quality data using mathematical concepts (Feroni & Galvão, 2018) or the integration of various projects carried out in professional educational training (Paula-Acosta et al., 2018). A study by Cotič et al. (2015) used second-grade students to explain and found that using the integrated methods of mathematics and environmental teaching and learning attained higher performance levels at all TIMSS taxonomies compared to traditional teaching and learning in mathematics. These outcomes indicate that integrating different disciplines in the early education process can help develop students' willingness to solve mathematical problems and ecological sensitivity.

However, there is a strong emerging interest in environmental education and a significant shortage of provisions for synthesizing mathematics, teacher training, and environmental instruction. Mathematics supplies tools for specifying and modelling individual and complex environmental spaces; unfortunately, these educational approaches are not combined with conceptual frameworks that would allow students to focus heavily on environmental matters. This research intends to fill this gap by developing a framework to bridge the gap between mathematics and education for enhanced ecological literacy. From the literature, it was established that there is a good possibility of linking mathematics with environmental education to improve students' learning and ecological literacy. Gürbüz and Çalık (2021) have explained that to encourage students' reasoning and for students to develop environmental concepts, mathematical modelling across content areas can be helpful. They are in tandem with the current learning theories that propagate intersectoral approaches.

Additionally, as Gardner et al. (2021) noted, ideas on the instructional integration of STEM disciplines, when delivered through supportive professional development programs, enable teachers to promote integrated teacher practices, including integrating mathematics with environmental education. Integrating another form of social justice, ecological considerations, into teachers' work was established to be feasible and made teachers' feelings regarding environmental education more positive. Implications of these findings point to the possibility of using interdisciplinary ecological education and mathematics to fill the gap in environmental literacy.

The global problems of sustainability require interdisciplinary methods of education in environmental disciplines. Consistent with Semerjian et al. (2004), they emphasize that such education involves the collaboration of different disciplines exemplified by an interdisciplinary graduate program. Focht and Abramson (2009) opine that the reason for advancing interdisciplinary measures is that the current environmental trends are only getting worse. While senior environmental education has conveyed a great deal of informational knowledge, using mathematics, students can assess how scientists use data and models to prevent environmental alterations and shifts. The sustainable agenda means integrating understanding based on the modern natural and social sciences and humanities, humanitarian, technical, engineering and applied studies, and envisioning the improvement of human quality and health of the systems. The significance of generating interdisciplinary plans is that the urgency of the emerging environment worsens, so there are no familiar methods to respond. Previous environmental education has relied on the use of information and, therefore, lacks practical ways of demonstrating the data and models of change esthetics that have been developed. In this way, mathematics has been included to ensure students have a feel of what it feels like to learn about environmental changes more practically. Eagan et al. also prove that an integrated approach to the courses taken at the graduate level, such as the cultural, business, and environmental sciences, enhances seminar communication skills among learners. These studies shed light on the fact that only an interdisciplinary environmental education fosters the development of thinking abilities, problem-solving skills, and adequate communication skills that are fundamental for providing appropriate solutions to those environmental issues. Integrating these disciplines will strengthen people's perception of environmental problems and promote better actions.

Research Objectives

The objectives of this research are to:

1. Examine how environmental concepts can be effectively integrated into mathematics curricula at various educational levels.
2. Assess the perceptions of teachers and students regarding the interdisciplinary blending of mathematics and environmental education.
3. Evaluate the challenges and opportunities of using mathematical models to raise environmental awareness.
4. Propose innovative pedagogical strategies that can enhance the integration of environmental topics into mathematics education, promoting sustainability and ecological literacy.

Literature Review

Environmental education has become essential in solving major world issues, including climate change and species loss. Conventional learning methods focus on acquiring content knowledge in a didactic manner, which, according to Freeman et al. (2014), practical and context-linked teaching-learning approaches and inter-related subject incorporation, especially with mathematics, foster increased students' interest and understanding. Due to the goal of mathematical learning, which can foster data analysis in solving problems in and out of classrooms, it enlightened students more on environmental concepts. Research indicates that it is possible to enhance students' critical thinking through mathematical models, enabling them to understand matters of resource management and sustainability, among other issues.

Therefore, there is increasing awareness of converging educational approaches in educational sectors, duplicating interdisciplinary subjects such as environmental and mathematics education. According to Aguayo and Eames (2023), this approach benefits the level of critical thinking and problem-solving on ecological conscience. However, Yang et al. (2022) indicate that after reviewing the literature, there is still a gap in knowledge as to how mathematics can be integrated with environmental education to enhance awareness at different levels of education. Besides, environmental education can also develop information technology applications that can increase its attractiveness and make intricate knowledge easier to grasp by using augmented reality tools, for example (Aguayo & Eames, 2023). Such an approach also capitalizes on the latest technological developments described by Peixoto et al. (2022) in their work on preventing global biodiversity loss through microbiome research: education-specific interdisciplinarity.

Also, Wardat et al. (2023) emphasized how applying AI tools such as ChatGPT to the Mathematics Learning Experience has improved understanding in Mathematics students by including response and instructional features. This method can be used in education within the field of environmental sciences by giving students the capability to assess ecological data through mathematical models properly. This approach enables a closer link between theoretical understanding and applying skills in solving environmental-related issues for information such as climate change and resource management.

Furthermore, Llemma's study on using mathematical models for environmental purposes shows that ecological processes, nature, and functions are best understood whenever students employ sophisticated mathematical instruments. Therefore, incorporating analytical mathematical notions into ecological education—integrating data analytics and statistical modelling, for instance—can foster critical [...]. This interdisciplinarity is particularly productive in developing critical thinking and creative problem-solving skills needed to solve environmental issues worldwide.

The challenges accompany the integration process of interdisciplinary education, especially when integrating two or more faculties, such as environmental science and mathematics. Another challenge described by Ciferri and Soldi (2021) is a lack of institutional support where curriculum constraints write off the need for cross-disciplinary learning. This is exacerbated by the lack of resources and professional development promoting crossing content areas. They also note that typical bureaucratic constraints, including curriculum pressures and standardized assessment, limit creativity in interdisciplinarity in teaching models.

Moreover, as Khan and Wells (2023) identified, limited research exists on how best to teach and assess subject integration, such as environmental science and mathematics. The existing assessment system is not built for the Multidisciplinary approach to learning and thus fails to accommodate the general assessment of this type of learning outcome. Even more detrimental is that the mismatch renders the implementation of interdisciplinary curricula all the more challenging.

Likewise, Oudenampsen et al. (2023) indicate that time constraints and the resulting workload pressures might be the main obstacles. Teachers can have difficulty managing interdisciplinary lesson planning with their current lessons, which can burn them out or cause them to do interdisciplinary work in a fake way. The lack of a focus on altering workloads means that changing to interdisciplinary teaching is not sustainable unless institutional changes are implemented.

Therefore, integrating environmental science and mathematics in learning improves students' interest and uniquely positions them to solve real-life environmental issues quantitatively. In the future, as more and more new educational strategies are adopted, the interconnection of these subjects will be critical in moulding a generation of environmentally conscious and numerically skilled learners.

Methodology

This study adopts a quantitative research approach, using a structured online survey to collect data from teachers and students across government and private schools, colleges, and universities in Bahawalpur. The primary aim is to assess how educators and students perceive the integration of environmental concepts into mathematics education and how this interdisciplinary approach could enhance ecological awareness.

Online surveys have become increasingly popular in educational research, offering unique advantages and challenges compared to traditional methods. Web-based surveys are generally superior to email surveys, though email can effectively recruit participants. Key methodological considerations include survey design, privacy, sampling, distribution, response rates, and piloting (Andrews et al., 2003). Ethical issues in educational survey research encompass dual teacher/researcher roles, informed consent, incentives, privacy, and data quality. A situated/process ethics approach is recommended to address ethical concerns throughout the research process (Roberts & Allen, 2015). Formulating research in the online survey format can also add to the necessary research capacity, especially when doing research with youth participants who usually embrace technological knowledge (Borden et al., 2006). However, various advantages can be accrued from online surveys, specifically since there are ethically reasonable means of conducting research that cannot be done in offline education (Roberts & Allen, 2015).

One hundred one participants were selected, including 55 teachers and 46 students studying at different educational establishments. Participants were selected across different academic years to capture integration across both secondary and tertiary institutions.

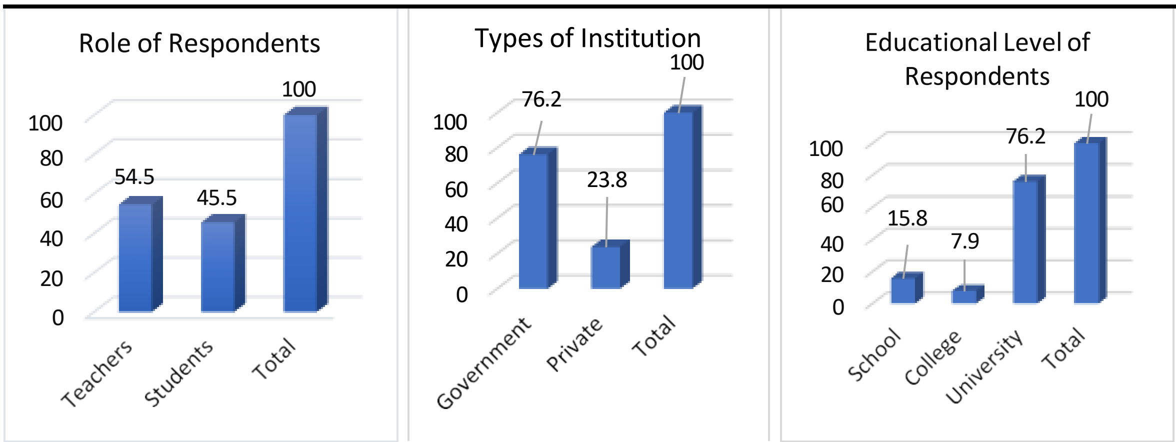
The online survey had 15 questions about the participants' profiles, interdisciplinary learning, and the editor's opinion of integrating environmental concepts with mathematics education. For attitudes towards this integration, Likert-scale questions were asked; the responses offered rich data about the prospects and problems of such an integration.

Descriptive statistics were computed using SPSS 2022. Percentage distributions were analyzed through inferential statistics such as ANOVA tests and t-tests to determine differences in perception between different population subgroups (teachers and students, government and private institutions). Cronbach's alpha was used to test the reliability of the survey instrument and check whether the responses were consistent with the instrument itself.

Results and Discussion

Demographic Representation

Figures 1 (a, b and c): Demographic Representation of Respondents



(a) (b) (c)

The demographic data of respondents indicates a fairly balanced representation between teachers and students, with 54.5% of the participants being teachers and 45.5% being students. In terms of the types of institutions represented, a significant majority of 76.2% of respondents are from government institutions, while 23.8% come from private institutions. Regarding the educational level of respondents, most are affiliated with universities, making up 76.2% of the sample, followed by 15.8% from schools and 7.9% from colleges. Overall, the data highlights a diverse group of respondents across different roles, types of institutions, and educational levels.

The results indicate that both teachers and students view the integration of environmental concepts into mathematics education positively. A majority of teachers (70%) believed that blending these subjects could enhance students' understanding of environmental issues, while 65% of students expressed interest in learning environmental concepts through mathematics. Private institutions demonstrated a higher rate of enthusiasm for the interdisciplinary approach compared to government institutions.

Statistical Analysis

Table 1: Distribution of responses for each question on perceptions of environmental awareness through mathematics and education

Variable Codes	Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
PII-1	Environmental concepts should be integrated into mathematics curricula.	15.84	38.61	23.76	7.92	13.86
PII-2	I believe that mathematics can enhance students' understanding of environmental issues.	16.83	40.59	19.8	8.91	13.86
PII-3	Blending mathematics and environmental education would make learning more interesting for students.	14.85	41.58	16.83	11.88	12.87
PII-4	Mathematical models can effectively explain environmental challenges such as climate change or pollution.	14.85	42.57	16.83	12.87	12.87
EILO-1	The integration of environmental concepts into mathematics would improve critical thinking skills.	12.87	50.5	18.81	6.93	10.89
EILO-2	Students would better understand real-world environmental problems through mathematical analysis.	10.89	50.5	18.81	6.93	12.87
EILO-3	Blending these disciplines would lead to better problem-solving skills in environmental contexts.	19.8	43.56	16.83	10.89	8.91
EILO-4	Teachers are well-prepared to teach environmental concepts through mathematics.	18.81	33.66	19.8	12.87	14.85
CH_OPP_1	I believe that the current curriculum supports the integration of environmental education into mathematics.	0	22.8	31.7	24.8	20.8
CH_OPP_2	It is challenging to find appropriate mathematical models for environmental topics.	0	48.5	19.8	18.8	12.9
CH_OPP_3	More resources (e.g., teaching materials, training) are needed to effectively blend mathematics and environmental education.	0	55.4	27.7	5.0	11.9
CH_OPP_4	Interdisciplinary teaching (combining mathematics and environmental education) is a valuable innovation for schools and universities.	0	49.5	28.7	11.9	9.9

Codes: PII= Perception of Interdisciplinary Integration, EILO= Educational Impact and Learning Outcomes, CH_OPP= Challenges and Opportunities

Table 2: T-test Comparison of Responses Between Government and Private Schools for Perceived Integration of Environmental Concepts into Mathematics Education.

Variable Codes	Statements	T-statistic	P-value
PII_1	Environmental concepts should be integrated into mathematics curricula.	0.809543	0.420145
PII_2	I believe that mathematics can enhance students' understanding of environmental issues.	0.929825	0.354723
PII_3	Blending mathematics and environmental education would make learning more interesting for students.	2.471172	0.015175
PII_4	Mathematical models can effectively explain environmental challenges such as climate change or pollution.	0.948539	0.345165
EILO_1	The integration of environmental concepts into mathematics would improve critical thinking skills.	-0.3239	0.746695
EILO_2	Students would better understand real-world environmental problems through mathematical analysis.	1.096001	0.275737
EILO_3	Blending these disciplines would lead to better problem-solving skills in environmental contexts.	0.997845	0.320787
EILO_4	Teachers are well-prepared to teach environmental concepts through mathematics.	0.686462	0.494027
CH_OPP_1	I believe that the current curriculum supports the integration of environmental education into mathematics.	0.338	0.736
CH_OPP_2	It is challenging to find appropriate mathematical models for environmental topics.	-0.011	0.992
CH_OPP_3	More resources (e.g., teaching materials, training) are needed to effectively blend mathematics and environmental education.	1.259	0.211
CH_OPP_4	Interdisciplinary teaching (combining mathematics and environmental education) is a valuable innovation for schools and universities.	0.299	0.766

Codes: PII= Perception of Interdisciplinary Integration, EILO= Educational Impact and Learning Outcomes, CH_OPP= Challenges and Opportunities

ANOVA Analysis

Figures 2: F-Value One-way ANOVA (Respondents Role)

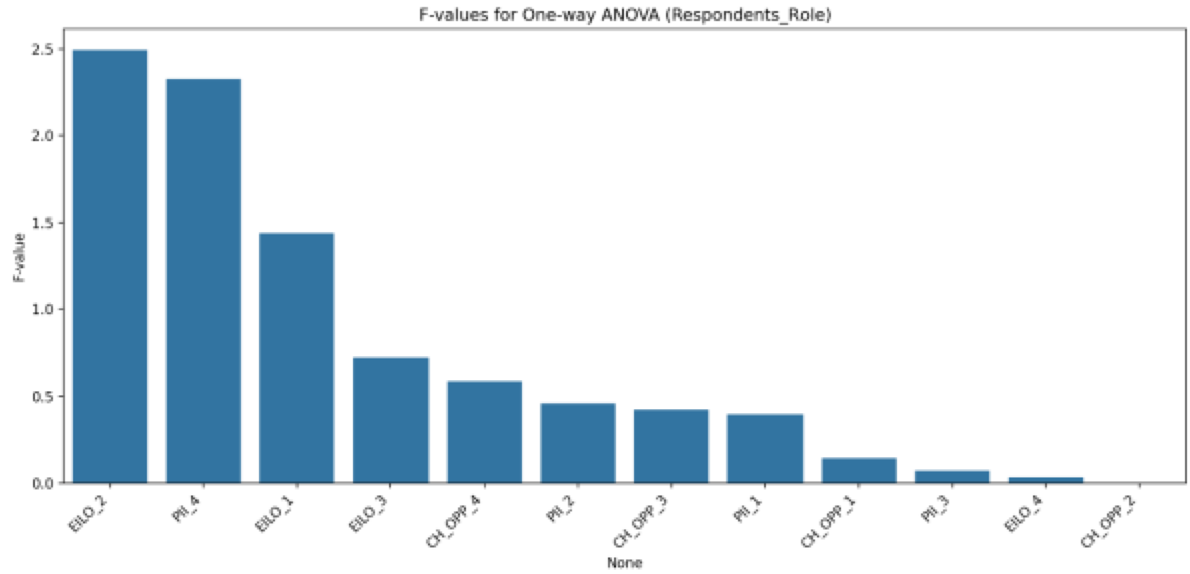
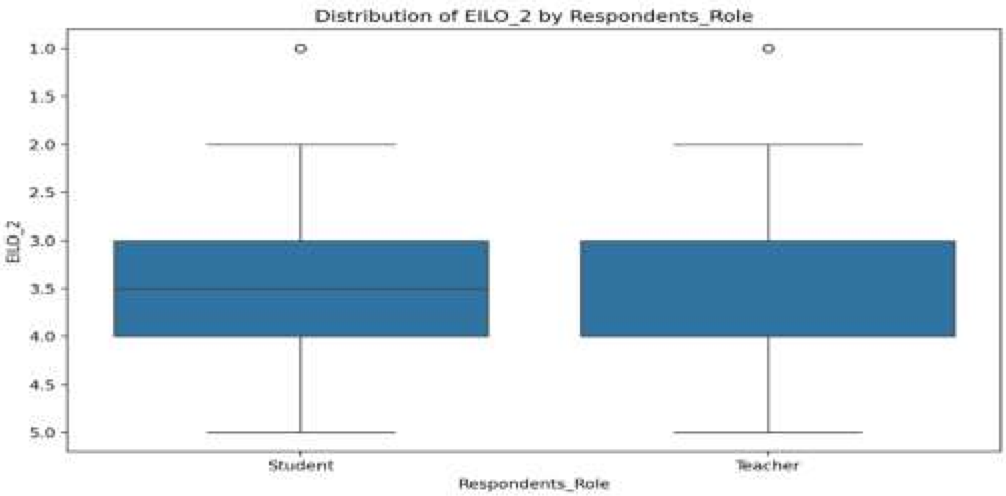


Figure 3: Distribution of Educational Impact and Learning Outcomes 2



The analysis shows no statistically significant differences between students and teachers for any of the questions (all p-values > 0.05). EILO_2 had the lowest p-value, but it's still not significant.

Table 3: One-Way ANOVA Results for Respondents' Role and Interdisciplinary Learning Constructs

	F-value	p-value	Significant
EILO_2	2.491788	0.117632	NS
PII_4	2.324547	0.130536	NS
EILO_1	1.438905	0.23318	NS
EILO_3	0.719627	0.398313	NS
CH_OPP_4	0.581672	0.447471	NS
PII_2	0.461187	0.498654	NS
CH_OPP_3	0.423902	0.516505	NS

PII_1	0.39786	0.52965	NS
CH_OPP_1	0.145927	0.703277	NS
PII_3	0.070988	0.790458	NS
EILO_4	0.033024	0.85617	NS
CH_OPP_2	0.001047	0.974247	NS

Codes: PII= Perception of Interdisciplinary Integration, EILO= Educational Impact and Learning Outcomes, CH_OPP= Challenges and Opportunities

Table 4: Strongest Correlation

PII_2	**PII_3**	0.71196528
PII_3	**PII_2**	0.71196528
PII_4	**PII_3**	0.70330954
PII_3	**PII_4**	0.70330954
PII_2	**PII_4**	0.69698526

Codes: PII= Perception of Interdisciplinary Integration, EILO= Educational Impact and Learning Outcomes, CH_OPP= Challenges and Opportunities

Table 5: Weakest Correlation

CH_OPP_1	**EILO_3**	0.221636867
CH_OPP_4	**CH_OPP_1**	0.187931572
CH_OPP_1	**CH_OPP_4**	0.187931572
PII_3	**CH_OPP_1**	0.182918772

Codes: PII= Perception of Interdisciplinary Integration, EILO= Educational Impact and Learning Outcomes, CH_OPP= Challenges and Opportunities

Discussion

The study's findings provide comprehensive insights into the perceptions of teachers and students in Bahawalpur regarding integrating environmental awareness into mathematics education. In a more detailed aspect, the responses, given by response distributions, t-test, and ANOVA, depict a general agreement on the advantages and difficulties inherent with this multidisciplinary paradigm.

Perceptions of Integration

The study results (Table 1) suggest high levels of agreement by respondents on the need to integrate environmental concepts in mathematics curricula, and many are aware of the opportunities to use mathematical models to understand environmental problems (PII-1, PII-2). More specifically, it is noteworthy that a good half of them believe that combining mathematics with the education environment should make learning more enjoyable (PII-3). Nonetheless, neutral and dissenting voices indicate that although there is appreciation, it is accompanied by concern about the actual ideas' application.

Educational Impact

The results depict a moderate level of consensus regarding the applicability of integrating environmental concepts to enhance criticality and real-world problem-solving abilities (EILO-1, EILO-2). There is also a recognition of the contribution of mathematical analysis in enhancing understanding of environmental issues. Nevertheless, the ambivalent results concerning the teachers' preparedness (EILO-4) can indicate a gap concerning the professional orientation towards interdisciplinary approaches.

Challenges and Opportunities

The challenges are different, but two are opinion-dividing: whether the current curricula can facilitate this integration (CH_OPP-1) and the generally recognized need for more resources (CH_OPP-3). The observed shouldering needs to identify suitable mathematical models (CH_OPP-2) underlines the urgency of implementing tailor-made strategies for this integration. Nevertheless, interdisciplinary teaching is an important innovation (FIN_OPP-4) and is beneficial.

Comparative Analysis of School Types

The T-test employed in Table 2 does not reveal many differences between the perceptions of government and private schools. However, a common opinion for two subjects- mathematics and environmental education (PII-3)- shows significant differences between government and private institutions. This can be due to disparities in institutional features, teaching-learning resources, or policies on adopting innovative teaching-learning practices and processes.

Role-Based Perceptions

In Table 3, the authors conducted an ANOVA, which reveals no significant difference between the teachers' and the students' perceptions of the various interdisciplinary constructs sampled from the various groups of students. This uniformity gives an impression of a shared appreciation of the prospects and concerns of incorporating the environment into mathematics and, hence, the notion of a shared perception across the divide of roles.

Correlational Analysis

Table 4 also shows high intercorrelations between major perceptions, including that mathematics can improve environmental knowledge (PII-2) and the perceived value of integrating subjects and students' interests (PII-3). This interdependent belief system forms the rationale for assimilating these disciplines in education. However, as presented in Table 5, there are no significant correlations between perceived curriculum support CH_OPP-1 and problem-solving skills; EILO-3 indicates systemic failures that require intervention.

Synthesis of Findings

The extent to which environmental concepts should be included in mathematics The study demonstrates that there is consensus in the literature supporting the idea of environmental concepts in mathematics education. Teachers and students understand the feasibility of inter-discipline integration when it comes to strengthening and developing the best features of critical analysis of numerous issues and the study of environmental problems, in particular. The large gap in the extent to which these two types of institutions support the integration of these disciplines implies that institutional differences could affect the nature and uniformity of interdisciplinary education. Eradicating such disparities requires sex-specific approaches and training, which are necessary for implementation.

Conclusion

In summary, the study affirms the possibility of increased use of concepts based on the environment when teaching mathematics while at the same time underlining the paucity of adequate curriculum support for this approach, lack of resources and preparation of teachers to undertake such innovative approaches. Positive associations between interdisciplinary approaches indicate the promise of more positive and attention-getting education. At the same time, negative correlations with systemic factors give clues about areas that need more adoption for wholesome learning. To fully unlock this benefit, it is essential that there are strategies for increased resources and curriculum changes, which can help to overcome these impediments to effective interdisciplinary education.

Future Recommendations

Based on the findings, several recommendations can be made for enhancing the integration of environmental awareness through mathematics education:

1. Curriculum Development: Educational authorities should develop and implement standardized curricula that integrate environmental concepts into mathematics at various educational levels. This curriculum should be flexible enough to accommodate different institutional needs while promoting a consistent approach to interdisciplinary learning.
2. Teacher Training and Professional Development: To address the challenges faced by teachers, particularly in terms of pedagogy, targeted professional development programs should be designed. These programs should equip teachers with the tools and strategies needed to effectively blend mathematics and environmental education, ensuring that they can convey complex environmental issues through mathematical models and data analysis.
3. Institutional Support and Resources: Government and private institutions should receive appropriate support and resources to implement interdisciplinary education. This includes providing access to relevant teaching materials, technological tools, and financial resources that can facilitate the integration of environmental concepts into mathematics classes.
4. Student Engagement and Active Learning: Innovative teaching methods that emphasize student participation and active learning should be promoted. These methods may include project-based learning, where students can apply mathematical concepts to real-world environmental problems, thereby enhancing their understanding of both subjects.
5. Research and Continuous Improvement: Further research should be conducted to explore the long-term effects of interdisciplinary education on students' environmental literacy and mathematical proficiency. Ongoing evaluation of implemented strategies will allow for continuous improvement and refinement of pedagogical approaches.

   In conclusion, while the integration of environmental awareness into mathematics education presents challenges, it also offers significant opportunities to foster environmental literacy and critical thinking among students. By addressing institutional disparities, supporting teachers, and promoting active learning, educational stakeholders can ensure that this interdisciplinary approach contributes to a more sustainable and environmentally conscious society.

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