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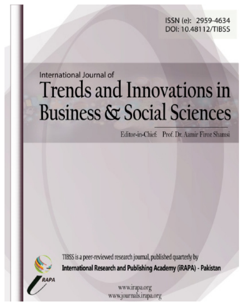

Research Article

Empowering Tomorrow: A Systematic Approach to STEM Education Pedagogy for Achieving Sustainable Development Goals and Students' Conceptual Understanding

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ABSTRACT

The purpose of this research was to compare three different approaches to STEM education in terms of their impact on students' retention of STEM concepts and their ability to apply those concepts in real-world contexts: project-based learning, problem-based learning, and inquiry-based learning. Sixty (60) students in 9th grade made up the study's research sample. A cooperative teacher assisted them in their education. Two groups were formed from the participants. In contrast to the experimental group, which received training based on STEM concepts, the control group received more conventional methods of instruction. A 2x3 factorial design was utilised in the quantitative and experimental studies. We used the conceptual understanding in STEM subjects test (CUSST) to quantify students' grasp of STEM concepts. The study's primary findings indicated that STEM instructional strategies increased students' conceptual comprehension. All three phases of teacher preparation (pre-service, induction, and in-service) should incorporate STEM (science, technology, engineering, and mathematics) instructional practices into the science curriculum and training modules. The incorporation of STEM fields has the potential to enhance science education programmes, methodology, textbooks, and curricula. Stakeholders may be able to use this study as a springboard to investigate current teacher professional development programmes for gaps.

INTRODUCTION

To end extreme poverty, the United Nations drafted the Sustainable Development Goals (SDGs) in 2015, environmental protection, and the promotion of peace and stability, with the target of achieving these objectives by 2030 (Silva & Oliveira, 2022). The UN Statistical Commission accepted the Inter-Agency and Expert Group on SDG Indicators proposed 230 indicators in March 2016. The 17 Sustainable Development Goals are intricately interconnected and cannot be separated from one another (Galiani & Quistorff, 2017). Education for sustainable development (ESD) programmes have recently become more popular (Wals, 2014), largely as a result of campaigns like the UN Decade of Education for Sustainable Development ESD is an educational technique that equips students with the necessary information, skills, beliefs, and mindsets that enable one to make thoughtful choices and act responsibly in pursuit of ecological sustainability,

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economic sustainability, and social justice (Silva & Oliveira, 2022). Science, technology, and innovation (STI) have always been recognised as essential factors that contribute significantly to economic growth and prosperity. STI will play a more prominent role in the new plan and in achieving the Sustainable Development Goals (Thibaut, et al., 2018). The achievement of several stainable Development Goals (SDGs) will primarily depend on the use of science, technology, and innovation (Vivekanandan & Pierre-Louis, 2020). Consequently, UNESCO has formulated educational goals for the SDGs to assist teachers and students (Henriques & Brilha, 2017). The incorporation of Science, Technology, Engineering, and Mathematics (STEM) into the educational system has great potential for attaining long-lasting advancements. All countries and relevant stakeholders will work together to implement this approach (Henriques & Brilha, 2017). The study conducted has established specific objectives and goals that will stimulate progress in vital areas that have a direct influence on both individuals and the environment over the next eight years. Multiple Sustainable Development Goals (SDGs) are directly or indirectly linked to Science, Technology, Engineering, and Mathematics (STEM) education and initiatives that have a direct correlation with the fields of Science, Technology, Engineering, and Mathematics (STEM) (Wals, 2014).

STEM Education and Sustainable Development Goals

Many Countries throughout the world have taken part in the transition and have integrated the United Nations SDGs into their Curriculum. STEM literacy encompasses the acquisition and comprehension of scientific, technological, engineering, and mathematical knowledge and concepts. STEM education emphasises a concept-driven methodology to develop students' analytical understanding and problem-solving abilities, enabling them to excel in diverse industries related to these subjects. Enabling folks to comprehend their interdependence and the imperative of developing these related skills. The method of teaching science, technology, engineering, and mathematics (STEM) concepts in two or more STEM domains using real-world examples to make connections across different areas of study and improve students' understanding of each. Kennedy and Sundberg (2020) agreed that this method is now essential in classrooms of the modern era. The development of effective STEM pedagogies that can contribute to this objective is complicated by the fact that various stakeholders have diverse understandings of STEM education and its regulation can be difficult (Martini et al., 2022). When thinking about STEM education, it can be challenging to conceptualize the epistemic barrier that arises when moving from one area of STEM knowledge to another (Leung, 2020). According to (English, 2016) there isn't a universal strategy for integrating STEM subjects. The need to better prepare students for STEM-related jobs has made it a top priority on a global scale to enhance STEM education (Thibaut, et al., 2018).

Next Generation Science Standards

The Next Generation Science Requirements (NGSS) consist of science curricular requirements designed for students in grades K-12. Standards define the benchmarks for the information and abilities that students are required to have and exhibit. The NGSS, also known as the Next Generation Scientific Standards, were developed to improve scientific education for students involved in the SDGs partnership. The purpose of developing the NGSS was to create a set of science standards for grades K 12 that are based on scientific principles and are up-to-date. These requirements provide local educators with the freedom to provide classroom learning opportunities that cultivate students' passion for science and prepare them for advanced education, career options, and civic involvement. The National Research Council (NRC) has formulated the Next Generation Scientific Standards (NGSS) as an all-encompassing structure for scientific instruction in grades K-12 in the United States. The NGSS framework integrates three dimensions that are combined into the standards to provide a more comprehensive approach to scientific instruction. All four areas—scientific research, engineering practices, cross-cutting concepts, and discipline core ideas—are covered by the three dimensions.

- Physical Sciences.
- Structure and Properties of Matter.
- Chemical Reactions/properties
- Developing models, release and absorption of energy, use of mathematical and computational thinking, equilibrium.
- Forces and Interactions
- Waves and Electromagnetic Radiation
- Life Sciences
- Earth and Space sciences
- Weather and climate
- Human sustainability

The proportion of individuals in Pakistan who are below the age of 30 has surged to an unprecedented grade, accounting for 64% of the overall population.

This trend is anticipated to persist at an elevated grade until at least 2050. Annually, almost 4 million individuals from Pakistan enter the labour force. If the unemployment rate and the percentage of the workforce remain constant during the next five years, it is projected that an extra 0.9 million jobs will be created per year. Hence, to increase the rates of labour force participation, it is important to provide an additional 1.3 million employment opportunities annually (Ahmad & Ahmad, 2018). A graduate need to possess the capacity to sustain themselves and contribute to their community (Rosenberg et al., 2023). To participate in activities involving risk, creativity, and productivity, it is necessary to have a favourable environment. Consequently, the government must take enough measures to promote education, employment, and participation (Ahmad & Ahmad, 2018). Pakistan's acquisition of tertiary STEM education is essential to cultivate a knowledgeable workforce capable of proficiently implementing modern teaching concepts and methods (Beymer et al., 2018; Duffy & Azevedo, 2015).

Regrettably, the tendency experienced a deterioration over several decades. The insufficient emphasis on science and maths instruction within our education system has resulted in a gradual decline in students' interest in these subjects. The crux of this growing problem resides in the urgent need for Pakistan to prioritise STEM education. Firstly, it is important to augment individuals' understanding of STEM. The outcomes strongly underscore the imperative of promoting STEM education in Pakistan. This consciousness will assist us in attaining a well-deserved position in the worldwide STEM arena for achieving the SDGs.

STEM Education and Sustainable Development Goals

STEM education and projects are directly or indirectly linked to several SDGs. Here are a few instances of Sustainable Development Goals (SDGs) that are related to STEM.

- SDG 4: Quality Education: Target 4.7 explicitly emphasises the significance of education in promoting sustainable development and fostering global citizenship. STEM education is essential for delivering high-quality education and cultivating the abilities needed in the modern day.
- SDG 5: The agenda is Gender Equality: One way to achieve this goal is to support girls' and women's interest in STEM fields. Reducing gender gaps across multiple industries is made possible by promoting female involvement in STEM subjects.
- SDG 6: Ensuring access to clean water and sanitary facilities: The STEM fields play a pivotal role in developing innovative approaches to water purification, sanitation technologies, and long-term water management.
- SDG 7: Ensuring universal access to cheap, clean energy is the focus of the seventh Sustainable Development Goal. Innovations in sustainable energy sources, energy efficiency improvements, and solutions to global energy crises must be driven by the STEM fields.
- SDG 9: Industry, Innovation, and Infrastructure: The development of innovative and environmentally friendly infrastructure and technologies relies heavily on STEM skills. All of this includes developments in transportation, communication, and industry.
- SDG 11: The development of sustainable, inclusive, and ecologically friendly cities is the primary focus of science, technology, engineering, and mathematics (STEM) fields to help build sustainable and smart cities by creating tools for efficient infrastructure, resource management, and city planning.
- SDG 13: Climate Action: STEM education is essential for growing a deep understanding of climate science driving progress in renewable energy, sustainable agriculture, and adapting to mitigating climate change.
- SDG 14: Life Below Water: The scientific, technological, engineering, and mathematics (STEM) fields are vital in understanding marine ecosystems, advocating for conservation efforts, and developing solutions to problems affecting the oceans and aquatic life.
- SDG 15: Land-Based Inhabitants: The successful management of terrestrial ecosystems, the advancement of sustainable agriculture, and the safeguarding of biodiversity all depend on the application of innovations produced by STEM fields.
- SDG 17: Achieving the Goals through Collaboration: Achieving multiple Sustainable Development Goals (SDGs) would need close cooperation between STEM education programmes, businesses, governments, and non-governmental organisations (NGOs).

These targets prioritise the significance of STEM education, research, and innovation in tackling diverse global challenges and attaining sustainable development. STEM fields are essential for progressing knowledge, technology, and solutions that support the objectives stated in the SDGs.

The Role of Pedagogy in STEM Pedagogy

Teachers can effect significant social change. who can provide the educational solutions that are required to fit within the framework of sustainable development. Their knowledge and abilities are crucial for changing educational institutions and procedures to support sustainability. However, there hasn't been much progress in efforts to properly prepare educators for the use of STEM pedagogy. To properly address STEM subjects, teacher education needs to be realigned with the subject matter and instructional methodologies. Including STEM in pre-service and in-service teacher education programmes is one recommended action (United Nations Educational & Organization, 2014) In the United States, the majority of schools have embraced the Whole Institution strategy recommended by UNESCO, which is more efficient. This approach can be applied specifically to STEM education, requiring a comprehensive transformation of the entire educational institution. This comprehensive strategy seeks to integrate sustainability into every facet of the educational institution. The process entails reassessing the curriculum, campus procedures, organisational ethos, student engagement, leadership and administration, community connections, and research (Sayed & Ahmed, 2015). Thus, the institution serves as an exemplar for the learners. Sustainable learning settings, such as eco-schools or green campuses, enable educators and learners to incorporate sustainability ideas into their daily routines, promote the development of skills and knowledge, and prioritise complete education.

Innovating Teaching Methods

The following instructional strategies are used approaches for teaching students STEM

- Project-Based Learning (PjBL)
- Problem-Based Learning (PBL)
- Inquiry-Based Learning (IBL)

Project-based learning (PjBL) is a very effective educational strategy for incorporating STEM into grade-grade courses. This strategy entails student-centred studies that revolve around a particular topic and are guided by a set of objectives. The investigations culminate in the creation of a broadly defined product or technique. Projects cultivate an atmosphere of discourse, innovation, troubleshooting, investigation, simulation, and experimentation, and are relevant to students across all grade grades and disciplines, with a particular emphasis on the STEM field.

Although there are some shared features between this approach and PBL, the crucial distinction is in the requirement for students to critically investigate and assess a given situation. This necessitates a heightened amount of cognitive processing, as the problem at hand typically lacks a singular definitive solution. This method fosters innovation, collaboration, and effective guidance. An illustration of problem-based learning (PBL) involves instructing students to develop their entrepreneurial strategies aimed at addressing a societal requirement. To highlight the student's role in the learning process, which is the primary goal of inquiry-based learning, students are encouraged to ask as many questions as they like regarding the subject matter. Learning in this way helps students hone abilities like questioning, problem-solving, and critical thinking. The pupils will have the freedom to choose their questions because it is a student-led activity. Inspiring students to think critically and creatively is the teacher's job.

Purpose of the Study

Considering the aforementioned advancements in STEM education and their impact on the job of teachers, we assert that STEM is an essential requirement of the 21st century. Merely incorporating STEM into science education programmes is insufficient; what we require are proficient science teachers for STEM.

- To determine the effect of STEM instructional strategies on the achievement of sustainable development goals and students' conceptual understanding.
- To determine the effects after the Implementation of STEM instructional strategies on students' conceptual understanding in the content area of STEM (Science, Technology, Engineering, and Mathematics).

Question of the Study

- How do STEM instructional strategies affect the achievement of sustainable development goals and students' conceptual understanding?
- How does the Implementation of STEM instructional strategies influence students' conceptual understanding within the content area of STEM (Science, Technology, Engineering, and Mathematics)?

Hypotheses of the Study

H_{01} There is no significant difference in the achievement of Sustainable Development

Goals and students' conceptual understanding between groups exposed to traditional instructional methods and those exposed to STEM instructional strategies.

H_1 The integration of STEM instructional strategies has a significant positive effect on the achievement of the Sustainable Development Goals (SDGs) and students' conceptual understanding compared to traditional instructional approaches.

H_{02} There is no significant difference in the conceptual understanding of STEM content between students taught traditional instructional methods and those taught to STEM instructional strategies.

H_2 Students who are taught STEM instructional strategies will demonstrate a statistically significant enhancement in their conceptual comprehension within the STEM curriculum area, in contrast to students who receive traditional instructional approaches.

Conceptual Framework

This study seeks to investigate the pedagogical practises necessary for the effective incorporation of STEM education into the curriculum. The objective of this study is to lay the groundwork for the creation of a STEM competence framework by understanding the underlying concepts and foundations of each subject involved. The goal is to illustrate the interconnectedness and possibilities for increased cohesion within the STEM domain. Students' STEM skills and conceptual comprehension in STEM courses were examined in this study to identify the effect of STEM educational methodologies. Experimental, Relationship between Variables, and Variables were the sub-categories of the conceptual framework. In this research, the researcher added all selected topics from our science subjects (Biology, Physics and Chemistry) and Mathematics according to NGSS standards for developing the test for the experimental group.

METHODOLOGY

There were two types of variables. The primary independent variable in the study is the implementation of STEM instructional methodologies and STEM education in the experimental group. To achieve this objective, the study used STEM studies. Furthermore, the research also considers teaching/ learning methodologies as an additional independent variable, with a focus on their effects on the control group. The objective of this study was to assess the grade of Conceptual Understanding among students in STEM disciplines (Science, Technology, Engineering, Mathematics).

Data Analysis

Statistical procedures such as t-tests and One-Way ANOVA were applied to the acquired data using SPSS, version 26. A study was conducted to examine the impact of STEM instructional tactics on students' conceptual understanding. item-wise and as a whole. After obtaining results from the analysis, the findings were reported. There were two steps of data analysis.

- The students' responses to the achievement test were recorded in a data file. The data obtained from the Written test was analysed using SPSS software, specifically version 24. This analysis involved calculating Cronbach's alpha reliabilities, as well as determining the means and standard deviations.
- Paired sample t-tests were used to compare the mean gain score of the experimental group and control group, and effect size was calculated.

Research Design

This design involves two groups viz. Experimental group and control group.

Both the groups were pre-tested and later on treatment was provided to the experimental group whereas the control group was treated without manipulating the variable. After completing the treatment, both groups were again tested. The gain score of each group was calculated by subtracting the pre-test score from the post-test score. The effectiveness of the manipulated variable was determined by comparing the mean gain score of both the experimental group and the control group. The students were classified into three distinct groups, namely high achievers, moderate performers, and low achievers. Given the existence of two distinct groups in the independent variable, instructional methodologies, and the inclusion of three diverse groups in the grouping variable. Hence, the present investigation was designed as a 2x3 factorial design.

Table 1

2x3 Factorial Design highlighting students' strengths across domains of Academic Performance

Group	Achievement Grade			
	High	Average	Low	Total
Experimental Assemblage STEM Instructional Strategies	10	10	10	30
Control Group Traditional Method	10	10	10	30
Total	20	20	20	60

Table 1 indicates that the average proficiency grade of all students in both the Experimental Group and Control Group was determined to be identical. The mean proficiency grade of all students in the experimental group was determined to be sixty (60).

Table 2

Ability Grade of Students among Groups

Ability Grade of Students among Groups (Pre-test)					
Experimental Group			Control Group		
Ability Grade	No. of Student	Mean Score	Ability Grade	No. of Students	Mean Score
Low Achievers	10	43.30	Low Achievers	10	44.50
Average Achievers	10	58.60	Average Achievers	10	54.25
High Achievers	10	78.30	High Achievers	10	74.00
All-over Mean	30	60.00	All-over Mean	30	57.58

Instrumentation

A standard written test assessed 9th-graders' STEM knowledge. The test was designed to meet curriculum goals. Test development followed normal processes. The test included two grades. The first tier had MCQs, and the second required pupils to justify their choices. Students had to choose the right beginning grade and justify it with a later grade. Content for STEM tests. The first tier included multiple-choice questions (MCQs), and the second required pupils to justify their selections. Students had to choose the correct initial grade response and justify it with a subsequent grade response. Information on STEM Subjects Test content.

Development of Conceptual Understanding in STEM Subjects Test

Designing the Conceptual Understanding in STEM Subjects Test (CUSST) to assess students' understanding of STEM ideas was the major goal. (Nieswandt, 2007) defines conceptual comprehension as broad and deep knowledge. This study examines and defines STEM competency, which includes the knowledge, skills, attitudes, and concepts of the four STEM disciplines. The Conceptual Understanding in STEM Subjects Test (CUSST) used the SNC Punjab curriculum. Physics, chemistry, biology, and mathematics were taught to 9th-grade science and computer science students. The themes followed the National Research Council and Next Generation Science Standards (NGSS) main areas.

Table 3

Item Wise Analysis of CUSST

Subjects	Groups	Test	Mean	SD	%age	Sig
Science	Experimental Group	Pre-test	18.70	0.00	24%	0.00
		Post-test	22.21	0.00	68%	0.00
	Control Group	Pre-test	14.68	0.00	16%	0.00
		Post-test	18.00	0.00	28%	0.00
Technology	Experimental Group	Pre-test	15.54	0.00	22%	0.00
		Post-test	21.94	0.01	63%	0.00
	Control Group	Pre-test	9.8	0.00	7%	0.00
		Post-test	16.92	0.00	23%	0.00
Engineering	Experimental Group	Pre-test	14.92	0.00	17%	0.00
		Post-test	20.00	0.00	60%	0.00
	Control Group	Pre-test	6.00	0.00	5%	0.00
		Post-test	9.65	0.00	7%	0.00
Mathematics	Experimental Group	Pre-test	13.83	0.00	15%	0.00
		Post-test	22.00	0.00	68%	0.00
	Control Group	Pre-test	8.22	0.00	7%	0.00
		Post-test	10.60	0.00	8%	0.00

The examination of Table 3 uncovers the null hypothesis, which posits that there is no substantial disparity in the comprehension of STEM subject matter among pupils taught traditional instructional methods. Those taught STEM instructional strategies were rejected. This rejection was based on the significant t-value, df, mean score and the value of standard deviation.

Table 4

Mean Gain Scores of Experimental and Control Groups on Low-grade Students in CUSST

Difference Between Mean Gain Scores of Experimental and Control Groups on Low-grade Students in CUSST						
	N	M	SD	df	t	Sig-v
Control-Group	10	11.9	0.9			
Experimental-Group	10	18.6	1.7	21	-10.023	0.00

Note: * $p < .01$

The rejection decision was made because of the very significant t-value of -10.023, calculated with 21 degrees of freedom. This was supported by a p-value of .000, which is lower than the predetermined significance limit of .01. Hence, it can be deduced that there is a significant discrepancy in the mean improvement in conceptual comprehension scores on the STEM examination between low-grade children who were instructed using conventional approaches and those who were taught using STEM instructional techniques. In addition, low-achieving children who received instruction using STEM teaching strategies obtained higher scores (mean = 18.6, standard deviation = 1.7) compared to low-achieving students who were taught using conventional teaching methods (mean = 11.9, standard deviation = 0.9). The difference between the means was significant.

Table 5

Mean Gain Scores of Experimental and Control Groups on Average Grade Students in CUSST

Difference Between Mean Gain Scores of Experimental and Control Groups on Average grade Students in CUSST						
	N	M	SD	df	t	Sig-v
Control-Group	10	19.9	1.7	18		
Experimental-Group	10	29.6	2.9	18	-10.910	0.00

Note: * p < .01

Table 5 shows that the highly significant t-value of -10.910, computed with df = 18, was deemed to be significant as p =.000 < α =.01. This led to the decision to reject the sample. Therefore, it can be said that there is a notable difference between average-grade students' mean gain scores on conceptual understanding in STEM courses taught using traditional methods and STEM teaching strategies. Additionally, average-grade pupils who were taught using STEM instructional methodologies outperformed those who were taught using traditional teaching methods (M = 19.9, SD = 1.7) in terms of performance (M = 29.6, SD = 2.9). The degree to which the means differed (mean difference = 9.7, 93%).

Table 6

Mean Gain Scores of Experimental and Control Groups on High-grade Students in CUSST

Difference Between Mean Gain Scores of Experimental and Control Groups on Average grade Students in CUSST						
	N	M	SD	df	t	Sig-v
Control-Group	10	19.9	1.7	18		
Experimental-Group	10	29.6	2.9	18	-10.910	0.00

Note: * p < .01

Based on the information provided in Table 6, the decision to reject the hypothesis was taken due to the very significant t-value of -10.060, which was judged to be significant with a p-value of .000, which is less than the significance level α of .01. Therefore, it can be inferred that there is a substantial disparity in the average increase in conceptual knowledge in STEM among high-grade students who were taught using traditional methods compared to those who were taught using STEM instructional strategies. In addition, high-achieving students who were instructed using STEM teaching methodologies achieved higher scores (M = 39.6, SD = 3.6) compared to high-achieving students who were taught using traditional teaching methods (M = 21.9, SD = 1.9). The magnitude of the mean difference is 17.7 with a 95% confidence interval.

Table 7

Descriptive Analysis of Conceptual Understanding of STEM Test (CUSST)

One Sample Statics for Conceptual Understanding of STEM Test CUSST					
Groups	Test	Test Items	Mean	Std. Deviation	Std. Error Mean
Control Group	Pre-Test	25	9.400	5.3541	1.0708
	Post Test	25	11.560	4.4636	.8927
Experimental Group	Pre-Test	25	13.480	4.8573	.9715
	Post-test	25	18.560	4.2139	.8428

Table 7 indicates in the descriptive analysis of CUSST that the average score of the control group rose from 9.400 in the pre-test to 11.560 in the post-test. The standard deviation reduced from 5.3541 to 4.4636, signifying a decrease in variability. The standard error of the mean was reduced, indicating enhanced precision in the assessment of the post-test mean. The average score of the experimental group rose from 13.480 in the pre-test to 18.560 in the post-test. The standard deviation decreased from 4.8573 to 4.2139, suggesting a decrease in variability. The standard error of the mean was reduced, indicating enhanced precision in the assessment of the post-test mean. Both groups exhibit a rise in average scores from the pre-test to the post-test. The experimental group exhibited consistently higher mean scores than the control group, both before and after the trial.

The experimental group exhibited lower variability and higher precision in mean estimations compared to the control group, as indicated by the standard deviations and standard errors. To summarize, these findings indicate that the experimental group, which was exposed to various STEM educational methodologies, showed a significant enhancement in conceptual comprehension in comparison to the control group.

Table 8

Findings related to the Effect size of CUSST

Effect size of Conceptual Understanding of STEM Subject Test (CUSST)							
Groups	Test	t	df	Sig	Mean Differ-ence	Lower	Upper
Control Group	Pre-Test	8.778	24	.000	9.4000	7.190	11.610
	Post-Test	12.949	24	.000	11.5600	9.718	13.402
Experimental Group	Pre-Test	13.876	24	.000	13.4800	11.475	15.485
	Post-Test	22.023	24	.000	18.5600	16.821	20.299

Table 8 indicate that the t-test yields a statistically significant result, showing a notable disparity between the pre-test and post-test scores in the experimental group. The significant increase of 18.5600 indicates a noteworthy enhancement in conceptual comprehension from the initial assessment to the final assessment. Both the control and experimental groups exhibit statistically significant enhancements in conceptual comprehension from the pre-test to the post-test.

The experimental group, which was subjected to several STEM instructional methodologies, exhibits a greater mean difference, suggesting a more significant enhancement in comparison to the control group. Both groups' 95% confidence intervals for mean differences do not contain zero, bolstering the results' statistical significance. The t-test results show that STEM education improves students' conceptual knowledge. The significant improvements in the control and experimental groups demonstrate this. In particular, the experimental group benefits more. The statistical data support the researcher's claim that students' conceptual comprehension differs between pre and post-tests for both control and experimental groups. A statistically significant difference suggests rejecting the null hypothesis. This suggests that different teaching methods affect students' conceptual understanding and SDG achievement.

Discussion

In an ideal situation, Stem instructional strategies are expected to achieve the objective is to cultivate students' competencies that enhance their employability and prepare them to fulfil the current workforce requirements, by the vision of the Sustainable Development Goals (SDGs). set by the UN) for the 21st century. However, in the current situation, the traditional teaching method is used. There is a big gap between traditional and teaching through STEM instructional strategies in secondary school, this study is being conducted by assuming that replacing traditional teaching methods with "STEM instructional strategies" for classroom instruction on secondary grade students may produce change. There is no quality research in the Pakistani context for implementing the "ESD" or "STEM" in the curriculum. This research will be the foundation for the importance of Education for Sustainability and education for 21st-century skills.

The rationale behind choosing public schools was to facilitate the implementation of affordable STEM education for kids in the public school system, with a particular focus on girls. The inclusion of STEM in educational institutions is limited to a select few private sectors due to the high cost of STEM kits and the implementation of activity-based curricula. In the given scenario, a researcher from the private sector has obtained authorization from the education department to experiment with a current educational institution, thereby bridging the divide between private and public sector research.

CONCLUSION

Ultimately, the utilization of STEM teaching methods has clearly shown a substantial influence on the attainment of Sustainable Development Goals (SDGs), as indicated by the outcomes of both pre and post-experimental assessments. The findings indicate that incorporating STEM ideas into education extends beyond conventional methods, providing a transformative experience that is in line with the worldwide objective of sustainable development. The group that underwent STEM educational methodologies demonstrated a significant enhancement in their comprehension of concepts about SDGs. The statistical analyses, which involved t-tests, demonstrated significant disparities between the pre-test and post-test results in both the control and treatment groups. These findings indicate that implementing STEM teaching methods results in quantifiable enhancements in students' comprehension of concepts. STEM educational practices can foster the development of 21st-century abilities, including critical thinking, problem-solving, cooperation, and technical literacy. These abilities are crucial for equipping students to navigate a constantly evolving environment and contribute to the attainment of Sustainable Development Goals (SDGs).

Recommendation

Develop STEM (science, technology, engineering, and mathematics) courses that span disciplines. All of the issues in the real world are connected.

- Give students real-world experience through project-based learning. Foster critical thinking, collaboration, and creativity by assisting students in solving real-world problems that are in line with the SDGs.
- Incorporate virtual reality, robots, and artificial intelligence into STEM subjects. As a result, they are ready to work with the technology of the modern day and are motivated to come up with creative, long-term solutions.
- Encourage pupils to think globally by incorporating SDGs into STEM curricula. Encourage cultural

competency and global responsibility by facilitating student engagement across multicultural backgrounds.

- Work on critical thinking abilities first. Like the workers of the modern day, design projects and activities that push students to think critically, creatively, and analytically.
- Remove barriers to STEM education based on gender, socioeconomic status, or cultural background for all students. Inclusion and diversity in STEM fields necessitate resolving gender gaps.
- Make CPD opportunities available to STEM teachers. Modern skills and SDGs instruction necessitate familiarity with cutting-edge pedagogical practices, tools, and strategies.
- Encourage collaboration between schools, corporations, research institutions, and community organisations. Allow students to interact with STEM professionals and experts to learn about real-world applications.
- Teach STEM with environmental sustainability. Implement SDG 13-aligned projects on sustainability, renewable energy, conservation, and climate change.
- Use realistic assessments to assess students' real-world knowledge application instead of standardised testing. Presentations, project portfolios, and performance-based assessments are examples.
- Promote lifelong learning. Encourage inquiring, adaptive, and self-directed learning to prepare kids for STEM's fast-changing sectors.

Competing Interests

The author has declared that no competing interests exist.

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