https://doi.org/10.33472/AFJBS.6.10.2024.4339-4347

African Journal of Biological Sciences

Research Paper Open Access

STEM PEDAGOGY-BASED LEARNING ACTIVITIES IN PHYSICS FOR ENHANCING INTERDISCIPLINARY APPROACH AT THE SECONDARY LEVEL

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Article History Volume 6,Issue 10, 2024

Received:28 Apr 2024

Accepted : 06 May 2024

doi: 10.33472/AFJBS.6.10.2024.4339-4347

Abstract

In this study, attempt to construct *STEM pedagogy-based learning activities in physics for enhancing interdisciplinary approach at the secondary level.* The study evaluates the effectiveness of STEM pedagogy-based learning activities in physics. To examine the effectiveness of this model, 98 students were chosen for the study. It was determined through the use of appropriate statistical techniques that the data was analysed in order to examine the significance of hypotheses formulated within this context. For the analysis of data, the major statistical techniques are the computation of the coefficient of correlation, the critical ratio, the, and the analysis of covariance (ANCOVA). During the course of the research, it was found that significant differences exist between the experimental and control groups with regards to the posttest scores of STEM pedagogy-based learning activities in physics at secondary level

Introduction

STEM refers to a field and curriculum focused on education in the disciplines of science, technology, engineering, and mathematics. Small-group discussions are well-established as an effective pedagogical tool for promoting student learning in STEM classrooms. However, there are a variety of factors that infuence how and to what extent teachers use STEM discussions in their classrooms, including both their own STEM content knowledge and their perceived ability to facilitate discussions. Teachers engaged in a series of STEM pedagogy discussions. The objective was to enhance their STEM content knowledge and their proficiency in conducting discussions, there by empowering them to design and deliver effective STEM instruction in their own classrooms using small-group formats. The outcomes revealed that teachers actively engaged in substantive STEM discussions, dedicating the majority of their time to posing authentic questions related to content that aligned with various science and engineering core.

Furthermore, most teachers incorporated STEM pedagogy discussions into their end of program lesson plans. Follow-up interviews conducted a year later indicated that a subset of teachers had significantly increased the use of discussions in their STEM classrooms. In conclusion, the study presents a significant contribution by employing a practice-based approach to professional development. This approach not only enhances teachers' content knowledge but also equips them with the skills to effectively implement this knowledge through STEM pedagogy discussions in their classrooms. Therefore, the findings highlight an innovative pedagogical strategy that could be employed to support teacher education and facilitate the development of enriched curricula for STEM students.

Science

Promotes curiosity, exploration, inquiry, and problem-solving, frequently through experimentation and investigation.

Technology

Encourages the use of simple tools such as crayons, rulers, pulleys, and wheels, as well as more complex ones such as microscopes and computers

Engineering

Promotes the utilisation of materials, encourages design, craftsmanship, and construction, fostering comprehension of the mechanisms behind how and why things operate.

Mathematics

It promotes creativity and process development, and allows children to visually represent the concepts they are learning.

Keywords: STEM pedagogy, interdisciplinary approach, secondary level

Needs and significance of the study of stem pedagogy

- STEM fields are crucial for technological advancement and economic growth, necessitating educators to prepare students for careers in these fields.
- STEM Pedagogy emphasises critical thinking, problem-solving skills and inquiry-based learning for success in the modern workforce.
- STEM education can help reduce disparities by providing quality education to underrepresented groups, requiring inclusive teaching methods and environments.
- STEM pedagogy instills a mindset of curiosity and lifelong learning, empowering students to continuously update their skills and adapt to new challenges.
- The National Science Foundation (USA)'s Judith A. Ramaley created the term STEM in 2001 to replace the earlier SMET abbreviation (Sanders, 2009). Both acronyms initially appeared to serve the sole purpose of referring to the Science, Math, Technology and Engineering disciplines and the professional working in them. NSF has later composed a list of STEM fields, including the industry-relevant areas of psychology, social science, and education and learning research.
- STEM now is used as brand name to describe the integration of science, technology, engineering, and mathematics in educational curricula.

- Currently in use definitions for the integrational models of STEM (science, technology, engineering, and mathematics) are:
- S- Technology is based on science, which studies and attempts to comprehend the natural world (NRC,1996, p. 24). Science studies the natural world and its contents. Several scientific methodologies are employed to investigate the meaning of the natural world, including "inquiry," "discovering what is," "exploring," and application of "the scientific method."
- T - However, according to the NRC (1996, p. 24), "The goal of technology is to make modifications in the world to meet human needs" (ITEA, 2000, p. 7) or "Technology is the modification of the natural world to meet human wants and needs." Technology involves creating, manufacturing, and developing products from natural materials to fulfill human needs and desires. The processes used to modify and transform the natural world include "invention," "innovation," "practical problem solving," and design.
- E- "Engineering is the profession in which one applies judgement to develop ways to economically utilise natural resources and forces for the benefit of mankind by applying knowledge of mathematics and natural sciences acquired through study, practice, and experience" (ABET, 2002). The philosophy of technology and engineering is closely related to each other.
- M- Mathematics is the science of patterns and relationship. It gives the science, engineering, and technology their own precise language. Technological advancements, like computers, encourage mathematics, while mathematics advancements frequently lead to technological improvements. A mathematical model that aids in technical design by simulating the possible operation of a suggested by STEM is one example of this.

Hypotheses

STEM pedagogy is effective in learning physics at the secondary level.

Objectives of the Study

- To find out the effectiveness of STEM pedagogy in learning physics at secondary level.
- To find out the interdisciplinary approach of the STEM pedagogy in learning physics.

Review of related literature and studies:

- 1. Dessy Francisca et al (2021). The study STEM Integrated Approach in Improving Students' Physics Conceptual Understanding. They found that a significant difference in the scores of the students before and after the conduct of STEM integrated was observed and a significant relationship was obtained between test scores of the students and level of students' agreement in the implementation of STEM pedagogy approach. Students' conceptual grasp of physics improved as a result of the STEM integrated approach. It is recommended that seminars, workshops, and in-service training should be organised for effective implementation of the STEM integrated in the classroom.
- 2. E Susanti et al (2021): Analysis of problem-solving ability of physics education students in STEM-based project-based learning.

- They concluded that students' problem-solving abilities have been at a high level with a percentage average of 79. The result of education that incorporates Project-Based Learning (PjBL) with a STEM focus. Students' capacity to plan, communicate, solve problems, and come to the proper judgements when faced with challenges are all enhanced by the learning process. Students can gain experience in organising, negotiating, planning, and setting conventions on who is in charge of each work, how it will be completed, and how information will be gathered and presented.
- 3. Angeles Dominguez et al (2023): The paper "Integration of Physics and Mathematics in STEM Education: Use of Modelling" highlights how physics and mathematics can be seamlessly integrated to improve learning outcomes and increase the robustness and versatility of models. The study finds a curricular gap between activities notwithstanding the encouraging findings. Finally, this study highlights the importance of using modelling and a student-centred approach to integrate physics and mathematics, laying the groundwork for future studies aimed at improving the efficacy of STEM education.
- 4. C. Teevasuthonsakul et al: Design Steps for physics STEM education Learning in Secondary School.
- The study's after-class evaluation results showed that students' happiness with the subject of physics and their ability to think critically were higher, both statistically substantially at $p<.05$. Additionally, educators were counselled to use the engineering design process, science, math, and technology principles as the cornerstone for developing case studies of issues and their resolutions.
- 5. Allen Leung et al (2020): Boundary crossing pedagogy in STEM education.
- This study proposes an interactive pedagogical framework and provides a provisional statement to relate the connective aspects that are important for the development of a STEM education that crosses boundaries. Situated learning, communities of practice, problem solving, and dialogical methods for learning are some of these aspects. and an object at the boundary. The application of this paradigm is demonstrated using a STEM case study from a Hong Kong school. A thoughtful observation about boundary-crossing STEM pedagogy closes the commentary.
- 6. Widayanti et al (2018): Future physics learning materials based on STEM education: Analysis of teacher and student perceptions.
- The findings of this study indicated that lesson plans, books, animation, stimulation, and videos were necessary as teaching materials to enhance STEM learning in the national curriculum. Components of book teaching materials to include core competencies, basic competencies, indicators, objectives, concept maps, pictures, videos, animations, material that is explained in detail in each chapter, detailed discussion, internet links, summaries, and questions. Core competencies, fundamental competences, goals, indicators, abducting, using common language, comprehensive information, and ease of comprehension are all included in the video. The information required to create physics lesson plans that cover Newton's law, temperature, heat, dynamic and static electricity, and stationary waves. It is anticipated that all instructional materials will be based on mobile or e-learning. The teacher has not begun using STEM-based teaching resources in the national curriculum. Therefore, in order to fully

support the national curriculum, STEM-based teaching materials must be developed in the future.

- 7. Muhammad abd Hadi Bunyamin et al (2020): Current Teaching Practice of Physics Teachers and Implications for Integrated STEM Education. Based on this study, it was discovered that the physics teachers' methods of instruction did not match their beliefs about integrated STEM education. Nonetheless, their ideas of integrated STEM education were comparatively accurate. It is important to assist physics teachers in converting their ideas of integrated STEM education into practical classroom instruction.
- 8. Asrizal Asrizal et al (2023): STEM-integrated physics digital teaching material to develop conceptual understanding and new literacy of students.
- The data analysis's conclusions show that using STEM-integrated PDTM improves students' new literacy and conceptual understanding. Data, technology, and human literacy are among the new literacy abilities that the pupils possess. These findings show that students' conceptual comprehension and new literacy abilities are successfully developed when STEM-integrated PDTM is used in physics instruction.
- 9. Aik-Ling Tan et al (2019):
- In The S-T-E-M Quartet research, the learning objectives for various professions may be more in-depth than others, depending on the problem that is being described. The S-T-E-M Quartet emphasises links between disciplines, but it also considers the strength of those connections—weak, moderate, or strong. A case study demonstrating the utilisation of the S-T-E-M Quartet teaching framework is provided to show how STEM tasks can be designed and evaluated using this framework.
- 10. Chen Chen et al (2023): In the study “The role of media in influencing students’ STEM career interest” , They found that watching STEM-related TV and online videos, as well playing STEM-related video games during high school, were positively associated with students’ STEM career interest at the beginning of college. However, they also found that STEM media consumption did not impact directly on STEM career interest, but acted through two intermediaries: STEM identity and three career outcome expectations: a high interest in self-development (enhancement and use of talents), and low interest in material status (money, fame, power) and in interpersonal relationships (helping and working with, other people).
- 11. Yu Chen et al, 2024: The study's findings, "STEM learning opportunities and career aspirations: the interactive effect of students’ self-concept and perceptions of STEM professionals," showed that the students' favourable opinions of STEM professionals positively correlated with their career aspirations and acted as a mediating factor in the relationships between aspirations and media consumption as well as educational opportunities. Furthermore, the aforementioned mediated route was contingent upon teenagers' STEM self-concept, meaning that their desires for STEM careers were exclusively associated with their perceptions of STEM professionals.

Analysis and Interpretation

To find out the effectiveness of STEM pedagogy in learning physics at secondary level

The hypothesis states that "STEM Pedagogy is Effective in Learning Physics at the Secondary Level". The experimental group and control group were compared with respect to their pre-test scores and post-test scores through critical ratio tests of significance for the STEM pedagogy in learning physics at secondary level. The details of the statistical analysis are presented in Table 1

Table: 1

- Critical ratio test of significance for difference between control and experimental groups with respect to STEM pedagogy in learning physics at secondary level.

Stem pedagogy	**Control Group**			**Experimental Group**			**Critical Ratio**	
	N_1	M_1	σ_1	N_2	M_2	σ_2	t	P
Pretest	49	6.12	1.97	49	6.20	1.25	0.24	.01
Post test	49	8.80	0.83	49	12.18	1.17	16.45**	.01

** Significant at .01 level of significance.

Table 1 shows that there is no significant difference between the control and experimental groups with respect to the pretest scores (CR = 0.24; *df*=97; P<0.01) for the STEM pedagogy based learning activities in physics for enhancing interdisciplinary approach at the secondary level. Significant difference was observed between the control and experimental groups with respect to posttest scores (CR = 16.45; *df* = 97; P<0.01) for the STEM pedagogy based learning activities in physics for enhancing interdisciplinary approach at the secondary level.

Comparison of the experimental and control groups with respect to the Adjusted post-test scores of STEM pedagogy in learning physics at secondary level

Table 2

Analysis of covariance of the Adjusted Post test scores for STEM pedagogy in learning physics at secondary level for the experimental and control groups.

Test	**Mean**		**Source**	**Sum of squares**	***df***	**Mean Square**	**F**	**P**
	Exp	Con						
Pretest (X)	6.20	6.12	Between groups	0.16	1	0.16	0.06	0.01
			Within groups	265.22	96	9.27		
			Total	265.39	97			

Post test (Y)	12.18	8.80	Between groups	281.18	1	281.18	266.46	0.01
			Within groups	101.31	96	1.06		
			Total	382.49	97			
Sum of Co deviates SS_{xy}			Between groups	6.78				
			Within groups	53.39				
			Total	46.61				
Adjusted Post test(Y.X)	11.76	8.40	Between groups	278.29	1	278.29	292.94	0.01
			Within groups	90.56	95	0.95		
			Total	368.85	96			

From Table 2 it is evident that the computed F_x ratio for the pretest scores for 98) is less than table values (F = 3.94; P<0.01 and F = 6.90, P <0.05). Therefore there is no significant difference between the experimental group and control group with respect to the pretest scores for. F_y ratio computed for the post test scores for (F_y = 266.46), is greater than the statistical table value (F = 3.94; P<0.01), which shows that the experimental group and control group differ significantly with respect to the posttest scores. The analysis of covariance computed from the adjusted post test scores for the shows that the calculated F ratio ($F_{Y.X}$ = 292.94) is significantly greater than the table value (F = 3.94; P<0.01). Further, from the adjusted post test it is evident that the experimental group ($M_{Y.X}$ = 11.76) differs significantly from the control group ($M_{Y.X}$ = 8.40) with respect to STEM pedagogy in learning physics at secondary school students for the experimental and control groups. Table 2 reveals that the ANCOVA converges to the finding that the STEM pedagogy in learning physics at secondary school students than the traditional method currently being practiced in the secondary schools of Kerala. The Hypothesis of the "STEM pedagogy is effective in learning physics at the secondary level." is therefore valid.

Major findings

1. There is no significant difference between the control and experimental groups with respect to the pretest scores (CR = 0.24; *df* = 112; P<0.01) for the STEM pedagogy in learning physics at secondary level.

2. There is significant difference between the control and experimental groups with respect to posttest scores (CR = 16.45; *df* = 112; P<0.01) for the STEM pedagogy in learning physics at secondary level.
3. There is significant difference between the control and experimental groups with respect to the adjusted post test scores for the STEM pedagogy in learning physics at secondary level ($F_{Y.X}$ = 292.94; *df* = 112; P<0.01). The experimental group ($M_{Y.X}$ = 12.18) differ significantly from control group ($M_{Y.X}$ = 15.61) with respect to the STEM pedagogy in learning physics at secondary level.

Conclusion:

The application of STEM pedagogy learning style shows a significant improvement in the students' conceptual knowledge of physics. Before and after the STEM pedagogy learning strategy is used, there is a significant change in the pretest and posttest scores. As a result, the STEM pedagogy learning style improved the students' capacity for conceptual comprehension and problem-solving.

Recommendations

Based on the study's findings, it is strongly advised to use STEM pedagogy as learning strategy and investigate its application in particular subject or discipline. Additionally, it is recommended that educators take part in training on how to use this teaching technique in terms of topic content delivery, style approach, and learning materials. This will enable the teachers to fulfill the learning competencies, particularly with regard to physics' abstract subjects.

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ENCOURAGING FUTURE LEGENDS IN STEM

As advocates of STEM learning, we now know that:

- Kids benefit from early STEM education.
- Engaging, hands-on curriculum influences STEM interest for years to come.
- The U.S. and other western countries are at risk of falling behind in STEM.
- The future of society depends on proficient STEM skills, both in academics and practice.