To Study the Impact of a STEM OER Course on Enhancing Teachers' STEM Knowledge and Skill Competencies

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Abstract

The world is confronted with numerous global issues such as climate change, terrorism, gender inequality, human rights violation, poverty, scarcity of fresh water and so much more. To address these problems, we require innovative solutions and integrated knowledge of STEM disciplines that can support the construction and implementation of impactful results. This has to commence at school level with the teachers building their own STEM competencies for classroom teaching so that they cascade it to students to enhace their competencies. The researcher created a STEM OER Course, 'Build your STEM competency' of four modules of duration 5 weeks for teachers to enhance their STEM knowledge and skills. The course was developed using the ADDIE model of Instructional Design and STEM Theoretical Frameworks. The researcher used a quasi-experimental design with school educators, assigning participants to experimental and control groups to assess the effectiveness of the course in enhancing their STEM knowledge and skill competencies for classroom teaching. The researcher used data collection tools for descriptive and inferential analysis and the results showed considerable progress on building teachers STEM competencies in the experimental group.

Keywords: *STEM Competency, educators, STEM Education.*

Introduction

Take a moment to observe the world around you, and you will notice that we are confronted with numerous global issues such as climate change, terrorism, gender inequality, human rights violation, poverty, scarcity of fresh water and so much more. Addressing these problems requires innovative solutions, and only the integrated knowledge of STEM disciplines can support the construction and implementation of impactful results. It empowers individuals and communities to offer solution to real-world challenges, encourages reliance on data as evidence, and fosters the use critical thinking and problem-solving skills to develop innovative solutions.
STEM is the acronym for Science, Technology, Engineering and Mathematics. Sometimes, people use the acronym STEAM where Arts is integrated and also STREAM where research is integrated. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply Science, Technology, Engineering, and Mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009)."

Review of Related Literature

The 'Review of Related Literature' chapter serves as a critical foundation for the current research as it provides a comprehensive analysis of existing studies, theories and concepts relevant to STEM Education and building STEM competency in teachers for classroom teaching.
Halliburton P (2024) in Australia highlights the use of Makerspaces to build confidence in STEM among Primary Preservice Teachers (PSTs). Makerspaces are collaborative environments that encourage creative use of tools and technology. In the study, 240 teachers were divided into groups to create STEM kits for their schools, with only 24 opting to use the Makerspace for their assignments. Observations and design portfolios were analyzed using Nvivo software, focusing on 'confidence' and 'Makerspace Influences'. The study found that while all participants felt more confident in teaching

STEM after using the Makerspace, this confidence was less pronounced compared to their overall STEM skills and knowledge. Collaboration was also seen as a key factor in boosting confidence. The research underscores the potential of Makerspaces to enhance PSTs' confidence in STEM, though it primarily relied on interviews for data analysis and could benefit from additional variables and pre- and post-intervention measurements.

Anita Juškevičienė's (2024) case study in Lithuania explores STEM teachers' motivation and engagement in professional development and career advancement. The study examines teachers' perceptions of career progression, professional development, and collaboration, using both qualitative and quantitative data analyzed with MAXQDA Analytics Pro. Key findings reveal that 80% of teachers view collaboration as essential, yet face challenges such as communication difficulties, lack of trust, and time constraints. Additionally, 60% report challenges in implementing STEM reforms and technology in classrooms. The study highlights the importance of innovative teaching methods to stimulate student curiosity, with 70% of teachers interested in non-traditional educational roles. It suggests that collaboration during working hours can improve work-life balance and emphasizes the need for strategies to enhance teacher engagement and motivation in STEM education, ultimately fostering an effective teaching environment.

Aim of the Study

The broad aims of the present study are as follow:

1. To design a STEM OER Course for school teachers.
2. To study effectiveness of an OER Course for school teachers in enhancing their STEM competencies for classroom teaching.

Research Questions

1. What is the impact of the STEM OER Course on enhancing teacher’s STEM competencies?
2. How does STEM competency development differ between teachers in the experimental group versus the control group?

Objectives of the Study

1. To study the pre- test and posttest scores of STEM Competencies for the control group.
2. To study the pre- test and posttest scores of STEM Knowledge quiz for the control group
3. To study the pre- test and posttest scores of STEM Competencies for the experimental group.
4. To study the pre- test and posttest scores of STEM Knowledge quiz for the experimental group.
5. To compare the pre-test and post- test scores of STEM Competencies between the experimental group and control group.
6. To compare the pre-test and post- test scores of STEM Knowledge Quiz between the experimental group and control group
7. To measure the relation between course task scores and post -test STEM competencies scores in teachers from the experimental group.
8. To measure the relation between course task scores and post -test of STEM Knowledge scores in teachers from the experimental group
9. To compute and compare the gain scores of STEM Competencies in Teachers from the experimental and control groups.
10. To calculate the effect size of the OER Course treatment on building STEM competencies among school teachers in the experimental group.

Hypothesis of the Study

1. There is no significant difference in the pre-test scores of STEM Competencies between the experimental and control groups based on knowledge, skills and abilities.
2. There is no significant difference in the pre-test scores of the STEM Quiz assessing STEM knowledge for School Teachers in the experimental and control groups.
3. There is no significant difference in the post-test scores of STEM Competencies between the experimental and control groups based on knowledge, skills and abilities.
4. There is no significant difference in the post-test scores of the STEM Quiz assessing STEM knowledge for School Teachers in the experimental and control groups.

5. There is no significant difference between the pre-test and post–test scores of the STEM Quiz for the experimental group.
6. There is no significant difference between the pre-test and post–test scores of STEM Competency in the experimental group on the basis of STEM knowledge, abilities and skills.
7. There is no significant difference between the pre-test and post–test scores of STEM Competencies in the control group on the basis of STEM knowledge, abilities and skills.
8. There is no significant difference between the pre-test and post–test scores of the STEM Quiz in the Control group.
9. There is no relationship between relation between course task scores and post -test STEM competencies scores in teachers from the experimental group.
10. There is no relationship between relation between course task scores and post -test STEM knowledge scores in teachers from the experimental group.
11. There is no significant difference in the gain scores of STEM Competencies between the experimental and control groups (Gain Scores = Post-Test – Pre-Test) on the basis of STEM knowledge, skills and abilities.
12. There is no significant difference in the gain scores of building STEM competency, as designed for an OER, among School Teachers in the experimental group (Gain Scores = Post-Test – Pre-Test) on the basis of STEM knowledge, skills and abilities.
13. The OER Course treatment has no significant effect on building STEM knowledge among school teachers in the experimental group, as measured by the effect size.
14. The OER Course treatment has no significant effect on building STEM competencies among school teachers in the experimental group, as measured by the effect size.

Methodology

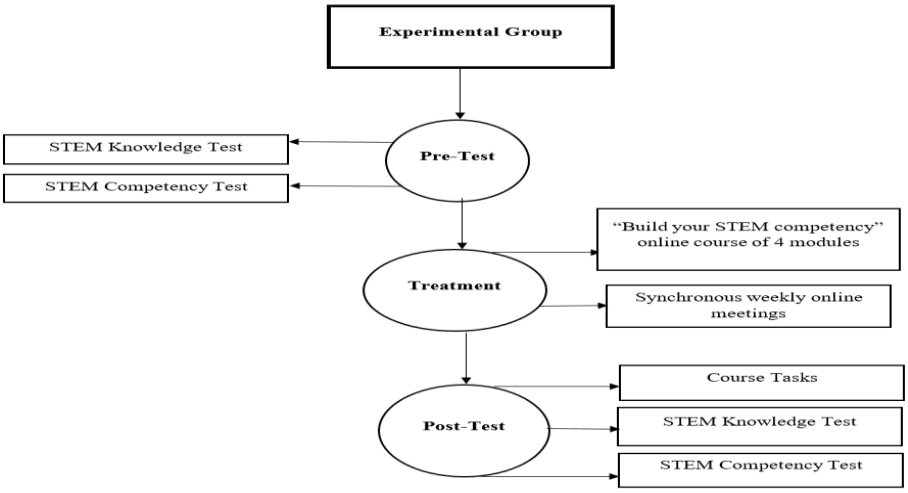
To address these questions, a quasi-experimental quantitative design study was deemed most appropriate. This approach ensured that the research questions were addressed comprehensively and that the findings are robust and reliable.
It involved assignment of participants to experimental Group A and control Group B without random assignment using quasi -Experimental design (figure 1). Both groups were administered a pretest and a posttest but the treatment X i.e course learning was offered only to the experimental group A. Test scores to measure STEM knowledge, online survey and course tasks to measure STEM competencies were collected from experimental participants. Also, test scores and online survey were collected from control participants at online platform to assess whether the online STEM OER course relates to STEM competencies.

Group A Experimental O ____________X______________O
Group B Control O_____________________________O

Figure 1: *Quasi Experimental design adapted from Creswell, J. W., & Creswell, J. D. (2023)*

A treatment of the course along with synchronous weekly online meetings was given to experimental group as shared in Figure 2.

Fig. 2. Experimental Group design



No treatment was given to the control group and were subjected to only pretest and post-test.

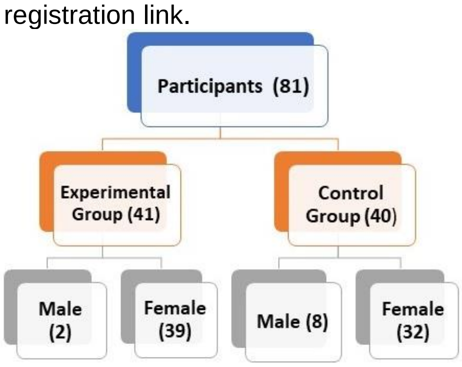
Variables

Variables are defined as characteristics of the sample that are examined, measured, described, and interpreted. In this study, there are two types of variables, viz, dependent variable and independent variables.

1. Independent variables are conditions which the experimenter influence or affect, outcomes in studies.
   In this research, the treatment i.e STEM OER course is the independent variable which the researcher will manipulate in order to determine its effect on the dependent variables.
2. Dependent variables: Given that the course aims to build teachers' STEM competencies, the dependent variable could include detailed measures such as:
   - **STEM Competency**: Assessment of teachers' knowledge and skills in STEM subjects, including content knowledge, problem-solving, and application of STEM concepts in classroom settings.
   - **Capacity to create STEM Lesson plan and STEM Course**: Evaluation of teachers' ability in designing lessons plans and STEM course for classroom teaching.

Sample Study

Selection Criteria - School teachers teaching either in Primary and Secondary Sections or both were selected. Teachers had to fill a registration link.



Data Collection Tools

1. **To measure STEM Competencies -** The self-assessment tool from Teach STEM has 35 questions that helps educators detect their strengths and weaknesses as a teacher when working on STEM topics in the classroom or other learning environment. The Artifex SAT was built and tested by university researchers.The validity of the tool was calculated after receiving feedback from a panel of 12 experts. The content validity ratio (CVR) was calculated for each item. For an

expert panel of 12 members, the CVR ratio accepted is 0.667. All questions met the minimum acceptable CVR threshold, indicating strong agreement among experts on their essentiality.
The reliability of the test was measured using the test -retest method with 36 participants. The correlation was evaluated and the result is 0.761.This suggests that the test is stable and reliable.

2. **To measure STEM Knowledge:** Participants in both Control and Experimental group were given the Silver Zone Foundation STEM Olympiad Sample Test Paper Class 7 from AglaSem. Points were assigned to the questions; responses were collected through Google form and the researcher received the marks. The reliability was measured using the split half method using the first part of the items as one part and second half as the other with 42 participants. The value of (r) calculated using Spearman-Brown formula is 0.8375. A reliability coefficient of 0.8375 suggests that the tool is consistent in measuring the intended construct.

Data Analysis and Results

Microsoft Excel were used to record the test scores, competency scores and tasks scores of participants. It was used for data manipulation and analysis. Both descriptive and inferential analysis was conducted to analyse the data.

Table 1. Analysis of pretest and posttest competency and knowledge quiz of control and experimental group

Variables	Groups	N	Mean	S.D.	‘t’ value	df	Significance at 0.05 level	Significance at 0.01 level
STEM Competency	Control pretest	34	28.45	3.167	-1.126	33	2.034	2.733
	Control posttest	34	29.062	2.992				
STEM Quiz	Control pretest	40	6.15	2.3810	-6.064	33	2.022	2.733
	Control posttest	40	8.45	2.630				
STEM Competency	Experimental pretest	36	29.646	3.531	-4.741	35	2.030	2.723
	Experimental posttest	36	32.243	3.139				
STEM Quiz	Experimental pretest	41	4.561	2.134	-10.295	40	2.021	2.704
	Experimental posttest	41	8.463	2.075				
STEM Competency	Control pretest	34	28.454	7.290	-1.987	33	2.034	2.733
	Experimental Pretest	34	29.954	3.530				
STEM Competency	Control posttest	34	27.448	7.350	-5.089	33	2.034	2.733
	Experimental Posttest	34	32.242	3.139				
STEM Quiz	Control pretest	40	6.15	2.381	2.987	39	2.022	2.707
	Experimental pretest	40	4.55	2.159				
STEM Quiz	Control posttest	40	8.45	2.630	-0.138	39	2.022	2.707
	Experimental posttest	40	8.525	2.062				

Analysis

1. The ‘t’ value to measure STEM competency for Control group is -1.126. The critical t-Value (two-tailed, α = 0.01) is 2.733 (approximate). Again, the absolute value of your calculated t-value (1.126592914) is less than the critical t-value (2.733), so the result is not statistically significant at the 0.01 level either. Results: Null hypothesis 1 accepted
2. The ‘t’ value to measure STEM knowledge quiz for Control group is -6.064. The absolute value of the calculated t-value (6.064) is also greater than the critical t-value at the 0.01 level (2.707). Since the absolute value of the calculated t-value exceeds both critical values, the

result is statistically significant at both the 0.05 and 0.01 levels. Results: Null hypothesis 2 rejected.

3. The 't' value to measure STEM competency for Experimental group is -4.741. The critical t-Value (two-tailed, α = 0.05) is 2.030. Since the absolute value of the calculated t-value (4.741) is greater than both the critical t-values at the 0.05 level (2.030) and the 0.01 level (2.723), the result is statistically significant at both levels. Results: Null hypothesis 3 rejected.
4. The 't' value STEM knowledge quiz for Experimental group is -10.295. The absolute value of the calculated t-value (10.295) is also much greater than the critical t-value at the 0.01 level (2.704). Since the absolute value of the calculated t-value exceeds both critical values, the result is statistically significant at both the 0.05 and 0.01 levels. Result: Null hypothesis 4 rejected.
5. The 't' value for Control and experimental competency pretest is -1.987. The absolute value of the calculated t-value (1.987) is also less than the critical t-value at the 0.01 level (2.733). Since the absolute value of the calculated t-value does not exceed either critical value, the result is not statistically significant at both the 0.05 and 0.01 levels. Result: Null hypothesis 5 accepted.
6. The 't' value Control and experimental competency posttest is -5.089. The absolute value of the calculated t-value (5.089) is also greater than the critical t-value at the 0.01 level (2.733). Since the absolute value of the calculated t-value exceeds both critical values, the result is statistically significant at both the 0.05 and 0.01 levels. Result: Null hypothesis 6 rejected.
7. The 't' value for Control and Experimental quiz pretest is 2.987. Since the absolute value of the calculated t-value exceeds both critical values, the result is statistically significant at both the 0.05 and 0.01 levels. Result: Hull hypothesis 7 rejected.
8. The 't' value for Control and Experimental quiz posttest is -0.138. The absolute value of the calculated t-value (0.138) is also much less than the critical t-value at the 0.01 level (2.707). Since the absolute value of the calculated t-value does not exceed either critical value, the result is not statistically significant at both the 0.05 and 0.01 levels. Result: Null hypothesis 8 accepted.

Table 2. Relation between Task Scores and STEM competency in Experimental Group

Variables	Group	N	't' value	'r' value	df	Value of Significant level at 0.05 level	Value of Significant at 0.01
Task Scores Posttest Competency	Experimental Group	36	2.313	0.436	35	2.030	2.723
Task Scores STEM Quiz	Experimental Group	41	14.639	0.441	40	2.021	2.704

Analysis

For relation between task score and STEM Posttest Competency, the absolute value of the calculated t-value (2.313) is greater than the critical t-value at the 0.05 level (2.030), the result is statistically significant at the 0.05 level but not at the 0.01 level.
From the above table, it can be seen that 'r' value is 0.436 and this is a moderate positive correlation, indicating a moderate relationship between Task Scores and Posttest Competency. Result: Null hypothesis 9 rejected.
For relation between task scores and STEM Posttest knowledge quiz, the t-value (14.639) is much greater than the critical t-values at both the 0.05 level (2.021) and the 0.01 level (2.704). Since the absolute value of the calculated t-value exceeds both critical values, the result is **statistically significant** at both the 0.05 and 0.01 levels. Result: Null hypothesis 10 rejected.

Table 3. Gain scores in STEM Competencies among teachers in control and experimental groups

Variables	Groups	N	Average Gain Score	't' value (gain scores experimental, gain scores control)	df	Value of Significant at 0.05 level	Value of Significant at 0.01
STEM competency	Control Group	34	0.608	2.597	33	2.034	2.733
	Experimental Group	36	3				
STEM Knowledge Quiz	Control Group	40	2.3	3.075	39	2.022	2.704
	Experimental Group	41	3.902				

Analysis

1. The 't' value for gain scores in STEM competencies among teachers between control and experimental group for STEM competency is 2.597. The critical t-Value (two-tailed, α = 0.05) is 2.034. The critical t-Value (two-tailed, α = 0.01) is 2.733. Since the calculated t-value (2.597) > 2.034, we reject the null hypothesis at the 0.05 significance level. Since the t-value (2.597) < 2.733, we do not reject the null hypothesis at the 0.01 level. Thus, we can conclude that the Experimental Group showed a significantly higher average gain score (3) compared to the Control Group (0.608) at the 0.05 significance level.
2. The 't' value for gain Scores in STEM Knowledge Quiz Among Teachers in Control and Experimental Groups is 3.075. The critical t-Value (two-tailed, α = 0.05) is 2.022. The critical t-Value (two-tailed, α = 0.01) is 2.704. The calculated t-value (3.075) is greater than the critical value of 2.022. Since 3.075 > 2.022, we reject the null hypothesis at the 0.05 significance level. We can conclude that the Experimental Group has a significantly higher average gain score (3.902) compared to the Control Group (2.3). Results: Null Hypothesis 12 rejected.

Table 4. To calculate effect Size of the OER Course treatment on building STEM competencies among school teachers in the experimental group

Variables	Group	Mean	S.D.	't' value	Effect Size
STEM Knowledge Quiz	Experimental Pre-test	4.561	2.134	-10.295	1.85394
	Experimental Post-test	8.463	2.075		
STEM Competency Test	Experimental Pre-test	29.646	3.531	-4.741	0.777
	Experimental Post-test	32.243	3.139		

Analysis

1. The calculated t-value for STEM Knowledge Quiz is -10.295. It indicates a significant difference between the pre-test and post-test scores for the experimental group. This large t-value suggests that the improvement in scores is not due to random chance. The effect size of 1.85394 is quite large. Effect size measures the magnitude of the difference between two groups. An effect size above 0.8 is considered large, indicating a substantial difference between the pre-test and post-test scores.
   Thus, we can conclude that the experimental intervention had a strong and statistically significant impact on the STEM Knowledge Quiz scores. The educators in the experimental group showed a considerable improvement from the pre-test to the post-test. Results: Null hypothesis 13 rejected

2. The calculated t-value for STEM Competency Test is -4.741 indicates a significant difference between the pre-test and post-test scores for the experimental group. This suggests that the improvement in scores is statistically significant and not due to random chance.
   The effect size of 0.777 is considered a medium to large effect. Effect size measures the magnitude of the difference between two groups. An effect size between 0.5 and 0.8 is typically considered medium, while above 0.8 is large. Therefore, an effect size of 0.777 indicates a substantial improvement in the STEM Competency Test scores from pre-test to post-test. Results: Null hypothesis 14 rejected.

Conclusion and Recommendations

The quantitative analysis of the STEM OER Course, "Build Your STEM Competency," shows a significant positive effect on building teachers' STEM competencies in the experimental group. The task scores in the STEM course correlate with the development of STEM knowledge, with results of 0.441 for the Quiz and 0.436 for the STEM Competency Test. The experimental group had a significantly higher average gain score (3.902) compared to the control group (2.3), indicating the intervention's effectiveness. The difference in gain scores for STEM competency between the groups is statistically significant at the 0.05 level, with a t-value of 2.597. The effect size for the experimental group's pre-test and post-test scores is large (t-value of -10.295, effect size of 1.85394), confirming the course's impact. For STEM competency, the t-value of -4.741 and effect size of 0.777 indicate a significant improvement. Differences in STEM competency but not STEM knowledge between groups may be due to factors like additional workshops or intrinsic motivation. The researcher suggests further trials to test the course's efficacy across different demographics and share feedback to enhance the course.

Link to the Course: https://www.stemforeducators.com/

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