



Effect of STEM PBL on Student's Engagement

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ABSTRACT

The objective of this study was to assess the current level of comprehension of Chemistry concepts among students in the B.S.Ed Honours programme, specifically in Class B.S.Ed. Additionally, the study sought to examine the impact of STEM Project-based learning on student engagement and academic performance in Chemistry, as compared to the traditional teaching method, within the same group of B.S.Ed students. It was an experimental study in which STEM PBL was compared with traditional technique. A cohort of 80 students was chosen from the Federal College of Education Islamabad in order to conduct an accomplishment test. The purpose of this test was to assess the current level of comprehension of topics in the field of Chemistry among students enrolled in the B.S.Ed programme. The sample size for the investigation consisted of 80 participants. A total of 80 students were chosen, with 40 students assigned to the experimental group and the remaining 40 students assigned to the controls group. The students in the experimental group received instruction using STEM Project-based learning, whereas the students in the controlled group were taught using traditional methods. This instruction was provided over a period of four weeks. The Pre-Test and Post-Test assessments were administered to both the experimental and controls groups at the commencement and conclusion of the trial. A total of eight lesson plans were developed based on the direct instruction format, specifically derived from the Chemistry textbook, for the students enrolled in Class B.S.Ed. In order to assess the impact of STEM PBL on the academic performance of Class B.S.Ed students in the field of Chemistry, a statistical analysis was conducted to determine the significance of the difference between the average achievement scores of the experimental and controls groups. This analysis was carried out using a t-Test, with a significance threshold of 0.05. The data analysis indicates that the current level of comprehension of Chemistry ideas among students in Class B.S.Ed. falls below 50 percent. The experimental group demonstrated a statistically significant higher score on the post-test compared to the controlled group, indicating the superiority of STEM Project-based learning over the traditional method.



Introduction

Requirements of an individual regarding learning have changed drastically over the period, there are few facts which have affected greatly i.e., the rapid increase in population which sets high threshold standards of competition among students, and another fact which affected most is the development of technology. Hence it effectuated to adapt new techniques which may meet further requirements to comply with the intellectual capability of students due to said factors; certainly, traditional instruction methods are inadequate to fulfill the challenges. Deep analysis shows that students are not relaxed enough with the current learning environment with the traditional instruction system, because the students' involvement is not core but the instructor is the hub in the learning and teaching process (Mahnaz et al., 2023).

STEM education essentially employs a multidisciplinary method in which academic topics are linked together depending on a real-life context. In reality, integrated learning may create links between educational institutions, local communities, employment opportunities, and multinational corporations that enable it in the current economic era. According to Anna Permanasari (2021) STEM learning encompasses any methods that examine two or more STEM areas. By integrating and applying mathematics, technology, and/or science, STEM learning, when presented in the proper way, may result in meaningful learning Anna Permanasari (2021).

Additionally, STEM education may be utilized to concentrate on knowledge of the interrelated nature of the Systematic, technical, industrial, and mathematical areas as well as their importance for kids' lasting academic performance, trade and industry well-being, and public development Liang-Hui Wang (2022) .Several nations are currently implementing STEM education, and it is quickly becoming one of the major modes in education throughout the world. Many nations have started to train their citizens to discover STEM and have diverse skills that they may employ in modern life (Mahnaz et al., 2022b).

Educational institutes are collaborating with the national laboratories, the energy sector, the education sector, etc. to organize a new generation with the information connected to this advanced expertise in order to prepare maximum pupils to professions concentrate on Science, Technology, Engineering, and Mathematics (STEM) Sirajudin (Mahnaz et al., 2022a). Aiming to address the productiveness's expanding demand for great expertise, flexibility, and critical thinking to advance in their professions.

Objectives of the Study

The objectives of the study were:

- i. To identify the engagement level of students in the subject of chemistry at the B.S.Ed level.
- ii. To find out the effect of the flipped classroom on students' engagement in the subject of chemistry.

Research Questions

For the achievement of the first objective, the following questions will be addressed.

1. What is the engagement level of students in chemistry at the B.S.Ed. level?
2. What is the emotional engagement level of students in chemistry at the B.S.Ed level?
3. What is the behavioral engagement level of students in chemistry at the B.S.Ed level?
4. What is the cognitive engagement level of students in chemistry at the B.S.Ed level?

Hypotheses

- H01:** There is no significant difference between the effect of a STEM PBL and traditional teaching on students' engagement in the subject of chemistry.
- H02:** There is no significant difference between cognitive engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry
- H03:** There is no significant difference between the emotional engagement post-test score of students taught through STEM PBL and traditional teaching in the subject of chemistry.
- H04:** There is no significant difference between behavioral engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry.

Significance of the Study

The study can be helpful to the policymakers, curriculum developers, and administrators to introduce STEM PBL in schools as well as at college level which was to develop students' classroom engagement in the subject of chemistry and help them to improve learning and academic achievements.

The study may also be significant for prospective teachers to adopt STEM PBL which may empower students. It may help the students to develop involvement, interest, and motivation in science subjects. It can be significant for teachers to explore more teaching strategies that enhance students learning. This study may be helpful for future research and fill the literature gap.

Literature Review

Teacher Perspectives on STEM Education in Pakistan

A study by Hussain and Sultana (2020) examined the views of teachers on STEM education in Punjab province. The study discovered that instructors had a favourable attitude towards STEM education and understood the value of STEM abilities for their student's future success. However, the study also found that teachers faced challenges in implementing STEM education, including a lack of resources and a lack of student interest.

Another study by Yasin et al., (2020) examined the effect of STEM education on students' academic accomplishment and career aspirations in Pakistan. The research found that pupils who were open to STEM education and academic achievement and were more likely to pursue careers in STEM fields. However, the study also identified several challenges to implementing STEM education, including a lack of resources, trained teachers, and support from the government.

A study by Mahnaz, Mehmood, & Umer (2022) investigated the impact of teacher training on the implementation of STEM education in Pakistani schools. The research discover that tutors who received training on STEM education were more likely to implement STEM activities in their classrooms and engage their students in problem-solving and critical thinking activities. However, the study also highlighted the need for more resources and support from the government to fully implement STEM education in Pakistani schools.

Challenges and opportunities of stem education

Teachers have identified several challenges and opportunities related to STEM education at the secondary level in Pakistan. A study by Imran and Ahmad (2021) identified several challenges, including a lack of resources, inadequate teacher training, and a lack of student motivation. The

study also identified opportunities, including the potential for STEM education to improve student employability and increase innovation in Pakistan (Mahnaz et al., 2025).

Factors Influencing the Success of STEM Education Programs

Several factors can influence the achievement of STEM education programs at the secondary level in Pakistan. A study by Mahnaz et al., (2022) found that teacher expertise, student interest, and the availability of resources were critical factors in the success of STEM education platforms. The study also found that collaboration between teachers and industry professionals could enhance the relevance and effectiveness of STEM education.

Similarly, a study by Hussain and Sultana (2020) identified teacher expertise and student interest as critical factors in the success of STEM education. The research also stressed the necessity for teacher training and importance of collaboration between teachers, industry professionals, and policymakers.

Role of teacher in student engagement

As the learners' behaviors and aspects of the learning environment's perception impact the engagement of student. A teacher plays a highly momentous part in classroom and in learning of a student. His teaching should be reward based. On doing good thing she should encourage his students as this will help him to involve his students in classroom activities. At times he should discourage students as it is necessary to examine their engagement in classroom activities although along with several plans from active learning to conflict disengagement and consideration of the strengths of learner student's lack of interest as realized by teachers is the actual phenomenon within college classrooms. Students should not remain passive in class. A teacher should make his students active by involving them in conversation. The interpersonal interactions between students and teachers also stress the engagement of learners in class (Kiran et al., 2022).

Research Methodology

The conducted study is experimental, and the section describes the study sample, design, instrument, and procedure of the experiment.

Research Design

This study was quasi-experimental and pre-test and post-test nonequivalent group design based on intact classes was adopted. Taking pre-test from the treatment group, and another test after treatment as a post-test was also conducted but a parallel control group was also checked from the "Pre-Test" and "Post-Test". On the bases of the "Pre-Test" of both groups, the difference in the engagement of students was calculated. After treatment students' engagement was also calculated from the post-test and compared with the control group.

Population of Study

The population of the study was all students of Federal college of Education Islamabad, in the academic year 2023-24. There were 500 students in class B.S.Edu

Sample of the Study

The researcher used naturally assembled groups as intact classes sample from federal college of Education. There were 40 students as “Experimental Group” while 40 students were selected as “Control Group”. Experimental group was taught by the researcher himself by using STEM PBL Taught through traditional method of teaching to control group.. The researcher select these schools due to the ease of permission of conducting research work from the concerned authorities and also the ease to access for teachers, the control group was taught through traditional teaching and the experimental group was taught through the STEM PBL.

Instrument Used for the Study

The tool which was utilized for collecting the data of the given study was an engagement questionnaire. This tool was adopted from Muhammad Qamar ud Din (2020), and proper permission from the author of the tool was sought in annexed D. the tool was given before the start of the experiment, and the same tool was given after the experiment to measure the engagement of students to observe the effect of independent variables. i.e. flipped classroom.

Student Engagement Questionnaire

The researcher adopted a student engagement questionnaire to assess the involvement of students with their learning and the learning environment in terms of cognitive, emotional, and behavioral dimensions (Miller, Rycek, & Friston, 2021). The questionnaire included 30 items related to behavioral, emotional, and cognitive aspects of engagement.

Behavioral engagement focuses on students exhibiting positive behavior, such as following classroom rules and norms, and not engaging in problematic behavior such as absenteeism or causing disruptions (Finn & Rock, 1997). It also includes participation in learning activities in the classroom and demonstrating efforts, perseverance, attentiveness, inquisitiveness, and participation in classroom discussions (Birch & Ladd, 1997). Emotional engagement refers to the emotional responses and feelings of students in the classroom, including emotions such as anxiety, sadness, happiness, boredom, and interest (Skinner & Belmont, 1993).

Emotional engagement also encompasses students' emotions and feelings related to school, including happiness or sadness in school, boredom or interest in their work, and attitudes toward the teacher, assignments, and school in general (Fredricks, Blumenfeld & Paris, 2004). Cognitive engagement involves constructive coping with failure, a willingness to put in the effort, and flexibility in problem-solving. It also includes intellectual investment, a desire to go beyond what is required, focus, attention, immersion, and concentration (Skinner & Pitzer, 2012). The student Engagement Questionnaire contained two parts.

(a) **Part A:** Demographic Information

(b) **Part B:** It consisted of a validated instrument that was adopted based on 30 items (10 for behavioral, 10 for emotional & 10 for cognitive engagement. The content validity index was calculated by using the universal agreement method. The CVI value was 83 which is excellent (Rodrigues, Adachi, Beattie & McDermid, 2017).

Table 3.1: Summary of Student Engagement Questionnaire

	Detail of Items	Number of Items
Behavioral Engagement	1 – 10	10
Emotional Engagement	11 – 20	10
Cognitive Engagement	21 – 30	10

Validity of experiment

The validated tool was adopted, and the experiment was validated by different expert researchers and university teachers. Different activities were organized during class time. The experts were invited to observe the class and commented that there was a true nature of the STEM PBL and students were demonstrating engagement in that teaching-learning process. They compiled their suggestions for that area to be improved.

Addressing the Threats to Internal Validity

Internal validity refers to the extent to which the study design controls for extraneous variables and minimizes the possibility of alternative explanations for the observed treatment effects. By controlling for potentially confounding variables, researchers can have more confidence that the effects are due to the independent variable and not some other unintended factors (Gay & Airasian, 2000). Therefore, it is important to control for internal validity threats in a study (Campbell & Stanley, 1966).

There will be several possible threats to the internal and external validity of this research study. The researcher will act accordingly so that these threats will not likely arise or will be minimized. These are...

History

To address the potential influence of extraneous events on the results of the study, the researcher took steps such as selecting experimental participants who had no contact with the control group and ensuring that both groups were exposed to the same current events. The researcher also minimized the potential role of history threat by keeping the duration of the experiment as short as possible and ensuring that the participants did not receive any additional coaching before or during the intervention. These measures were taken to minimize the possibility of situations or events other than the intended treatment occurring between the “Pre_Test” and “Post_Test” and affecting the results.

Maturation & Testing

Maturation and testing processes will be carefully controlled and standardized in both the experimental and control groups. The study will be conducted over a limited time period to control for maturation effects. However, it is important to acknowledge that maturation cannot be completely controlled, as noted by Campbell and Stanley (1966). Steps will be taken to ensure that all participants are in the same physical, mental, and psychological state before and after the study. Additionally, since all participants are roughly the same age and will be affected by the experiment for a brief period, it is expected that the pre-test and post-test measures of students' engagement will not be affected by maturation.

Regression

The regression threat, or regression to the mean, denotes the statistical phenomenon whereby a group's aggregate performance on a metric tends to revert to the mean score of that metric, rather than progressing as anticipated (Campbell & Stanley, 1966). This tendency may pose a concern in

research projects. To mitigate regression threats, the study employed mixed-ability students to form homogeneous groups. Measures were implemented to avert regression by the utilisation of mean differences, irrespective of score ranges and attributes. Both groups exhibited comparable regression, irrespective of the therapy administered.

Diffusion of Treatment

The researcher will keep the two groups (experimental and control) as separate as possible during the experiment.

Intervention

The experimental treatment will be for a period of 40 study periods. The lessons were developed on the topics included in the syllabus of Chemistry in the Federal college of Education . According to STEM Project based approach. The hands on projects and videos were developed on the following topics.

- i. Electrochemistry
- ii. Corrosion and its prevention
- iii. Physical State of Matter
- iv. Intermolecular forces
- v. Structure of molecules
- vi. How can Potatoes conduct electricity
- vii. Electrochemical industries
- viii. Periodic table and periodicity of properties
- ix. Structure of Atoms
- x. Acids, bases, and salts
- xi. Acid-Base Solutions
- xii. Effect of acid rain on organic and inorganic substances

Videos (podcast, screencast) and lectures/notes were downloaded and prepared by the researcher keeping in view the 10 topics by using STEM PBL. There is a total of 40 working days, so each topic was covered in max 2 to 3 days. Hands on projects and teacher-made projects were shared.

- i. .Lewis's acid and bases
- ii. Organic compounds and their functional groups.
- iii. Methods of naming organic compounds
- iv. Hydrocarbons (alkanes, alkenes, alkynes).
- v. layers of atmosphere
- vi. Air pollutants
- vii. Acid rain and its effects
- viii. Ozone depletion and its effects
- ix. Type of hardness (temporary and permanent hard water).
- x. Solvay process.

Videos (podcast, screencast) and lectures/notes were downloaded and prepared by the researcher keeping in view the 10 topics by using flipped classroom. There is a total of 40 working days, so each topic was covered in max 2 to 3 days. Video lectures were downloaded from YouTube (ILM ke Dunia. Sabak foundation) and teacher-made videos were shared.

a. Procedure

The procedure of this study and the way the data was collected is summarized as:

STEM PBL

Students can collaborate in groups, observe their classmates throughout individual STEM projects, and gain insights from one another through project-based STEM learning. The social cognitive theory (Erdogan et al., 2016) and its direct relationship with the observation of others' behaviours in social interactions and experiences (Han, 2017) align with collaborative efforts in STEM project-based learning. In STEM PBL, students must adhere to multiple phases that delineate the problem, from product development to testing, in order to enhance the product. Thus, the phases enable students to methodically oversee their progress while the teacher, in a facilitative role, provides ongoing feedback.

In-Class Activities

Following Classroom activities were arranged:

Hands on projects

By using hands on STEM PBL technique student involve in projects taking keen interest in teaching learning process.

Presentation on topic

Presentation skills help to create innovative ideas when Students come up with creative talk, that overcome their nervousness and make them more motivated and confident. The students presented the topic in class and the teacher listened and checks their concept clarification. At the end of class, the teacher guide and appreciate them.

Question/ answer technique:

After the question/ answer session the teacher will know their level of understanding and interest.

Group discussion

In the group discussion; all the students actively participated to revise and sharing information related to that topic. Group discussions encourage students to learn from one another and they better understand when they discuss the course and topic in their own words and the teacher guides and helped them.

A post-test was arranged after that.

b. Data Collection

With formal Permission from the school administration data was collected by using the “students’ engagement scale” from the students of the B.S.Ed level chemistry class.

c. Data Analysis

Finally, the data were analyzed in the following ways:

- Overall engagement of B.S.Ed level students.
- Engagement levels (cognitive, emotional, and behavioral engagement) of B.S.Ed level students.
- Comparison from “Pre-Test” to “Post-Test” Scores of the control group and experimental group of cognitive, emotional, and behavioral engagement levels.
- Comparison from Posttest Scores of Controls and Experimental groups of cognitive, emotional, and behavioral engagement.

Analysis and Interpretation of Data

The first objective of the current study was to identify the engagement level of B.S.Ed level students, for this purpose to find the total engagement of secondary school students in the subject of chemistry and then to find its three levels, cognitive engagement, emotional engagement, behavioral engagement by taking their pre-test and then score them. Descriptive statistics were used to find the total engagement and its three levels.

Table 4.1: Total engagement of students at the B.S.Ed level

N	Minimum	Maximum	Range	Mean	SD
80	51	105	54	76	13.84

The total engagement of students had a mean value of M=76 that had remarkably different from the maximum value of 105. It showed a moderate level of student engagement.

Table 4.2: Engagement levels of B.S.Ed level students

Engagement level	N	Minimum	Maximum	Range	Mean	SD
Cognitive	80	10	37	27	24.87	5.84
Emotional	80	11	37	26	25.5	6.45
Behavioral	80	17	35	18	26	4.25

The cognitive engagement of students had a mean value of M=24.9 which was not closer to the maximum value that is 37, so it shows the poor cognitive engagement of students. The mean value of the emotional engagement of students was M=25.5, which is remarkably different from the maximum value. i.e 37. behavioral engagement of students had a mean value of M=26, which was so far from the maximum value that was 35, and that mean value also proved that the cognitive engagement level of students was also very low.

Data were analyzed by using descriptive statistics and answering the research questions. Descriptive statistics were applied to the pretest scores of both groups and found the value of total engagement. The mean value was M=76 and the max value was 105, mean value was not near the max value, its was showed a low level of student engagement in both groups before the start of the experiment. All the other research questions in which emotional, behavioral, and cognitive level of students was found in the 4.2 table, in which the mean value of cognitive engagement was M = 24.87, and the max value was 37, which showed a low level of cognitive engagement.

The mean value of emotional engagement was M=25.5 and the max value was 37, so the mean value was not near the max value so emotional engagement was also very low before the start of the experiment. The value of behavioral engagement was M= 26 and the max value was 35, so that difference showed the poor behavioral engagement of students in the pretest.

Comparison of student engagement

Table 4 3: Student's Engagement Comparison in "Pre and Post-Test" scores for Experimental Group

Group	Test	Mean	SD	Mean difference	Df	t-value	Sig(2 tailed)
Experimental	pre	76.60	14.56	23.65	39	11.60	0.000
N=40	post	100.25	9.33				

Student engagement had a mean score of $M=76.6$ in the pre-test and the mean score in the post-test had a mean value of $M=100.25$ in the experimental group. The t-value for the judgment of the pre-test and post-test was calculated as $t=11.60$, $p=0.00$ which is less than 0.05 value shows that there is a significant difference in students' engagement in pre and post-test by using paired sample t-test. It means students' engagement level becomes high in the post-test.

Table 4. 4: Student's Engagement Comparison in "Pre and Post-Test" scores for Control Group

Test	N	Mean	SD	Mean difference	Df	t-value	Sig(2 tailed)
Pre-test	40	76.22	13.25	5.78	39	2.296	.027
Post-test	40	82.00	8.34				

Students' engagement had a mean score of $M=76.22$ in the pre-test and the mean score in the post-test had a mean value of $M=82$ in the control group. The t-value for the judgment of the pre-test and post-test was calculated as $t= 2.296$, $p=0.027$ which is less than 0.05 value shows that there is a significant difference in students' engagement in pre and post-test. It means students' engagement level becomes high in the posttest.

Table 4.5: Overall engagement scores in the post-test for the control and experimental group

Group	Pre-test means	SD	Mean difference	Post-test Means	SD	Mean difference	t-value	Df	Sig(2 tailed)
Experimental N=40	76.60	14.57	0.38	100.25	9.33	18.25	9.21	78	0.000
Control N=40	76.22	13.26		82	8.34				

Table 4.5 indicates that the overall engagement of students of control group in the pre-test had a mean score of $M=76.22$ and mean score value of the experimental group was $M=76.6$, the mean difference value was 0.38, the mean score of control group had a value of $M=82$ and for experimental group the mean value is $M=100.25$ in their post-tests. An Independent t-test was applied to analyze the above data as the mean score of both groups were compared. Students of the "experimental group" achieved more scores in the "Post_Test" in average scores when compared with the result of the control group. the t-value for the comparison of control group and experimental group was $t=9.21$ at ($df=78$), $p=0.000 < 0.05$. this value was statistically significant as mentioned in the above table. It was also analyzed in the "Post_Test" means that after the intervention time period, the difference was $M=18.25$ as the mean difference. This was greater than in difference shown in table 4.1. This comparison was to show the effect of the STEM PBL on the student engagement of the experimental group.

Moreover, the t-value in control group was $t= 2.29$ which was near zero, which means there was not any significant difference. On the other hand, the t-value of the experimental group was $t=11.60$ which was far from zero and showed a significant difference. Therefore, the null hypothesis stating that "There is no significant difference between the effect of the STEM PBL and traditional teaching on student's engagement in the subject of chemistry was rejected." From this

table, it was clear that there is a significant difference between the effect of the STEM PBL and traditional teaching on student engagement in the subject of chemistry.

Comparison of Cognitive Engagement

Table 4. 6: Comparison of student's cognitive engagement "Pre & Post_Test" scores in experimental/control group.

Group	Pre-test means	SD	Mean difference	Post-test Means	SD	Mean difference	t-value	Df	Sig(2 tailed)
Experimental	24.7	5.48	0.27	32.37	3.52	04.37	5.23	78	0.000
Control	24.97	6.25		28.0	3.94				

Table 4.6 indicates that the cognitive engagement of students in the control group had a mean score of M=24.97 and for experimental group 'mean value' was M=24.7 in their pre-tests and their mean difference is 0.27, it shows that there is no difference in cognitive engagement in control and experimental group.

In "Post_Test" cognitive engagement of students for control group had a mean score of M=28.00 and "Mean Value" for experimental group was M=32.37 in their post-tests. An Independent t-test was applied to analyze the above data as the mean score of both groups were compared. The students of the experimental group achieved more scores in the post-test in average scores when compared with the result of the control group. the t-value for the comparison of the control group and experimental group was $t=-5.23$, at $(df=78)$, $p=0.000 < 0.05$. This value was statistically significant as mentioned in the above table. It was also analyzed in the post-test means that after the intervention time period, the difference was M=4.37. As mean difference. This comparison was to show that STEM PBL affect student cognitive engagement.

Therefore it was proved thatthere is a significant difference between cognitive engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry so, the null hypothesis "there is no major change amoung cognitive engagement "Post-Test" scores of students taught throughSTEM PBL and traditional teaching in the subject of chemistry" was rejected.

Comparison of Emotional Engagement

Table 4. 7: Comparison of student emotional engagement pre/post-test scores in experimental group/control group.

Group	Pre-test means	SD	Mean difference	Post-test Means	SD	Mean difference	t-value	Df	Sig(2 tailed)
Experimental	25.37	6.04	0.25	33.75	4.16	6.25	6.19	78	0.000
Control	25.62	6.90		27.40	4.97				

Table 4.7 indicates that the emotional engagement of students in the control group had a mean score of M=25.62 and the mean score of the experimental group was M=25.37 in their pre-tests

and their mean difference is 0.25, it shows that there is no difference in cognitive engagement in control and experimental group.

While for “Post_Test” emotional engagement of students for control group had a mean score of $M=27.40$ and the mean score of the experimental group was $M=33.75$ in their post-tests. An Independent t-test was applied to analyze the above data and the mean score of both groups were compared. Experiment group students achieved more scores in the post-test in average scores when compared with the result of the control group. the t-value for the comparison of control group and experimental group was $t=-6.195$, at $(df=78)$, $p=0.000 < 0.05$. This value was statistically significant as mentioned in the above table. It was also analyzed in the post-test means that after the intervention time period, the difference was $M=6.35$. As mean difference. This comparison was to show that STEM PBL affect students' emotional engagement.

Therefore it was proved with presented results that a huge difference is observed among emotional engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry so, the null hypothesis “there is no major difference between emotional engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry” was rejected.

Comparison of behavior engagement of students

Table 4.8: Comparison of student behavioral engagement pre-test and post-test scores for experiment group/control group.

Group	Pre-test means	SD	Mean difference	Post-test Means	SD	Mean difference	t-value	Df	Sig(2 tailed)
Experimental	26.52	4.87		34.12	3.28				
			0.9			7.52	11.45	78	0.00
Control	25.62	3.52		26.60	2.55				

Table 4.8 indicates that the behavioral engagement of students in the control group had a mean score of $M=25.62$ and the mean score of the experimental group was $M=26.52$ in their pre-tests and their mean difference is 0.9, it shows that there is no difference in behavioral engagement in control and experimental group.

In the post-test behavioral engagement of students of the control group had a mean score of $M=26.60$ and the mean score of the group i.e. “experimental” was $M=34.12$ in their post-tests. An Independent t-test was applied to analyze the above data as the mean score of both groups were compared. The students of the experimental group achieved more scores in the post-test in average scores when compared with the result of the control group. the t-value for the comparison of the control group and experimental group was $t=-11.45$, at $(df=78)$, $p=0.000 < 0.05$. This value was statistically significant as mentioned in the above table. It was also analyzed in the post-test means that after the intervention time period, the difference was $M=7.52$. As mean difference. This comparison was to show that STEM PBL affect student behavioral engagement.

Therefore it was proved that there is a substantial difference between behavioral engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry so, the null hypothesis “there is no significant difference between behavioral

engagement post-test scores of students taught through STEM PBL and traditional teaching in the subject of chemistry” was rejected.

Findings

The student engagement in the pretest was not significantly high, In the experimental group a mean value of $M=76$ that had remarkably different from the maximum value of 105, The engagement level of the control group in the pretest had a mean value of 76.22 and was also remarkably different from the maximum value, $t=120$ at $df(78)$ where $p=0.904$ which was >0.05 value in the pre-test, that shows the engagement of students in the experimental & control group was equal before treatment.

- i. The behavioral engagement of students in the experimental group had a mean value of $M=26$ that was not closer to the maximum value that is 35, so it shows the poor behavioral engagement of students. The mean value of the emotional engagement of students was $M=25$, which is remarkably different from the maximum value. i.e 37. The cognitive engagement of the experimental group had a mean value of $M=24$, which was way far from the maximum value that was 37, and that mean value also proved that the cognitive engagement level was less than the other two in the experimental group.
- ii. The behavioral engagement of the control group was also checked by a mean value of $M=25$ and the maximum value was 32, emotional engagement had a mean value of $M=25.6$ but the maximum value was 37, the mean value of cognitive engagement was $M=24.97$, which had a big difference from the maximum value of 36. All these levels of engagement with remarkably different showing the poor engagement of secondary school students, and the engagement level of students in the pre-test for both groups (control and experimental) was almost equal.
- iii. The experimental group exhibited a mean score of $M=76.6$ in the pre-test and a mean score of $M=100.25$ in the post-test. The t-value for the assessment of the pre-test and post-test was computed as $t = 11.60$, with $p = 0.00$, which is less than 0.05, indicating a significant difference in student engagement between the pre-test and post-test. It indicates that students' involvement levels increase throughout the post-test. Student involvement exhibited a mean score of $M=76.22$ in the pre-test, while the post-test mean score in the control group was $M=82$. The t-value for the assessment of the pre-test and post-test was determined to be $t = 2.296$, with a p-value of 0.027, which is below the 0.05 threshold, indicating a significant difference in student engagement between the pre-test and post-test. This indicates that the level of student engagement increases during the post-test.
- iv. The control group exhibited an overall student engagement mean score of $M=82$, whereas the experimental group achieved a mean score of $M=100.25$ in their Post-Tests. The experimental group students attained higher average scores in the post-test compared to the control group results. The t-value for the comparison between the control group and the experimental group was $t=9.21$ with degrees of freedom ($df=78$), $p=0.000$, which is less than 0.05. The post-test analysis revealed a mean difference of $M=18.25$ following the intervention period. STEM project-based learning enhances student engagement more significantly than the control group.
- v. The post-test cognitive engagement mean score for the control group was $M=28.00$, while the experimental group received a mean score of $M=32$. The t-value for the comparison between the control group and the experimental group was $t=5.23$, with degrees of freedom ($df=78$), $p=0.000 < 0.05$. The post-test analysis indicated a mean difference of $M=4.37$

following the intervention period. This comparison aimed to demonstrate that STEM PBL enhances student cognitive engagement more significantly than the control group.

- vi. In the post-test, the control group exhibited an emotional engagement mean score of $M=27.40$, while the experimental group achieved a mean score of $M=33.75$. The experimental group students attained higher average scores on the post-test compared to the control group results. The t-value for the comparison between the control group and the experimental group was $t=6.195$, with degrees of freedom ($df=78$), $p=0.000$, which is less than 0.05 . The post-test indicates that following the intervention period, the difference was $M=6.35$. This comparison demonstrated that the flipped classroom enhances student emotional engagement.
- vii. The behavioural engagement of students in the control group (post-test) had a mean score of $M=26.60$, while the experimental group had a mean score of $M=34.12$ in their post-tests. The experimental group had higher average post-test results compared to the control group. The t-value for the comparison between the control group and the experimental group was $t=11.45$, with degrees of freedom ($df=78$), $p=0.000$, which is less than 0.05 . This value was statistically significant. The post-test analysis indicated that the mean difference after the intervention period was $M=7.52$. As the average discrepancy. STEM PBL enhances student behavioural engagement.

Conclusions

The conclusions of this study were drawn based on the analysis of data and the findings of the study:

- i. STEM PBL enhances the behavioral engagement of students in the subject of chemistry for B.S.Ed students
- ii. Emotional engagement of students was also improved by using STEM PBL in the subject of chemistry for B.S.Ed students.
- iii. The STEM PBL has a positive effect on the cognitive engagement of students in the subject of chemistry for B.S.Ed students.
- iv. The STEM PBL had a positive impact on overall student engagement. The experimental group showed higher levels of engagement compared to the control group, and this positive effect was attributed to the use of the STEM PBL.

Discussion

This research study suggests that the STEM PBL approach can improve students' behavioral engagement in chemistry at the B,S,Ed level. This finding is supported by previous research by Flumerfelt & Green (2013), which found that increased interaction between teachers and students resulted in significant academic achievement and behavioral improvements. Behavioral engagement refers to students being actively involved in activities that require them to take initiative (Mehmood et al., 2022).

This study revealed that incorporating videos and class activities within the STEM project-based learning framework improved behavioural engagement, consistent with the activity theory and trace theory posited by Bouvier & Sahaba (2009) for identifying and monitoring interactions in conducted activities. Cothran and Ennis (2000) and Pociask and Settles (2007) (as mentioned in Sherab, 2013) assert that good communication, a nurturing attitude towards students' learning, active learning chances, and the implementation of cooperative learning strategies can significantly improve behavioural engagement. Additional elements that may influence student behaviour encompass student happiness and achievement, time on work, social and academic integration, and pedagogical approaches (Nadia et al., 2022).

The use of a STEM PBL strategy, which involves conducting activities such as Q&A techniques and discussions in class, has been shown to improve student engagement in chemistry for B.S.Edhonor students. Taylor and Statler (2013) suggest that emotional engagement, which is related to learning and is promoted by materials that encourage students to interact with the material and receive feedback, can be increased through the use of discussion boards and problem-solving activities in a STEM PBL. On the other hand, Newmann, Wehlage, and Lamborn (1992) argue that students can still learn effectively without being emotionally engaged in the topic. However, emotional engagement can help students to be more motivated and take responsibility for each other in completing tasks (Jones, 2012). In addition to emotional engagement, the STEM PBL has also been shown to improve cognitive engagement through the use of complex, higher-order questions that require students to explain, justify, and rationalize their responses with their peers (Chin, 2007; Barr, 2013). Wilson (2013) found that the use of a STEM PBL can increase student engagement and improve performance, and other studies have also supported the positive impact of the STEM PBL on student engagement in chemistry (Bibi et al., 2023; Khan et al., 2022; Shaheen et al., 2022; Bahadar et al., 2014). This current study adds to this body of research by specifically focusing on the use of the STEM PBL to improve student engagement in chemistry (Mahnaz & Kiran 2024a; Mahnaz & Kiran 2024b; Mahnaz & Kiran 2024c).

It was observed that during group discussions, students were more motivated and actively participated, and their interest level was heightened. Their creative thinking was also improved when they asked questions and linked the material to daily life examples.

This study was experimental, and students in both the control and experimental groups completed a questionnaire to assess their engagement. The same questionnaire was administered in both the pre-test and post-test. While efforts were made to ensure that students answered the questionnaire honestly, there is a possibility that some students copied answers from their peers, which may have impacted the results. Additionally, it is possible that not all students thoroughly read all of the shared materials. Despite these limitations, the research has shown that the STEM PBL approach can improve students' engagement in chemistry for secondary school students. This is a significant finding, particularly for Pakistani teachers, as it can inform future research on student engagement and potentially be applied to other difficult subjects.

Recommendations

The results of the study are beneficial both for teachers and students. For this purpose

1. The findings of the study indicate that STEM PBL strategy enhances students' engagement. It is recommended that teachers should use STEM PBL strategy during their teaching.
2. Keeping in view the effect of the STEM PBL on students' engagement, there is a need to conduct workshops or seminars, etc. for the teachers to train them for STEM PBL strategy in the schools.
3. The result of the study reveals that STEM PBL strategy improve the behavioral engagement of students. It is suggested that the disruptive behavior of students is managed by using STEM PBL and other activities.
4. To ensure students' emotional engagement teachers are recommended to create a positive learning environment in the classroom.
5. Cognitive engagement of students enhances through STEM PBL. It is suggested that teachers should engage students in academic tasks it will ultimately lead to attaining the learning effectiveness of the students by improving their performance.
6. The STEM PBL is a very effective strategy to enhance students' engagement in chemistry, educationist and stakeholders should plan to develop flipped classroom strategy in part of

our content, so that strategy could be embedded in the teaching and learning of sciences in Pakistan.

Future Research

The result of the study exposed new avenues for future researchers who intended to search for new concepts based on the results of the study, the following directions are being presented for future research:

1. Keeping in view the effectiveness and impact of STEM PBL strategy it is recommended that the effect of this strategy may be explored in science subjects like physics, biology, maths, etc.
2. Future research can investigate the effects of STEM PBL strategy on low graders and even at the university level.
3. In this research effect STEM PBL on students' engagement was checked and experimental design was used, but other studies could be conducted to explore the relationship and effect of STEM PBL on self-regulation, motivation, academic achievement, exam anxiety, and attitude in different subjects.

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