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Creativity, Critical Thinking, Problem Solving Ability And Academic Achievement In Chemistry Among B.Sc. Students

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Abstract

The progress of higher-order cognitive skills like creativity, critical thinking, and problem-solving is increasingly recognized as essential in chemistry education. These abilities not only enhance conceptual understanding but also prepare students for complex scientific challenges. The present research investigates the interplay between creativity (CR), critical thinking (CT), problem solving ability (PSA), and performance at B.Sc. chemistry students and specifically the impact of varied teaching methods. A questionnaire was administered to 600 undergraduate students using a structured form to evaluate self-assessed cognitive abilities and the effects of different instructional strategies. Results indicated moderate but inconsistent levels of CR, CT, and PSA, with high and statistically significant correlations found among these skills and academic performance (Pearson's $r = 0.963$–1.000, $p < 0.01$). Regression analysis also showed CR and CT to be strong predictors of chemistry academic achievement ($R^2 = 0.918$, $p < 0.001$). Moreover, the implementation of innovative pedagogical approaches, e.g., project-based learning, group work, and inquiry-based experiments, had a very high positive correlation with the acquisition of these higher-order thinking skills ($r = 0.707$–1.000, $p < 0.01$). These results complement the recent literature on education, highlighting the importance of active, student-centred teaching environments to promote higher-order thinking and academic performance. Future research should utilize longitudinal and qualitative methodologies in multiple settings in order to further clarify the dynamics of cognitive skill acquisition in science education. As a whole, the research stresses the need to incorporate novel pedagogical approaches to improve cognitive as well as academic performance in chemistry education.

Keywords: Creativity, Critical thinking, Problem solving ability, Academic achievement, Chemistry

1. INTRODUCTION

1.1 Background of the study

With the fast-paced changing world of science and technology, the need to prepare students with higher-order cognitive and intellectual abilities has never been so urgent. As a central scientific subject, chemistry not only requires a good understanding of theory and practice concepts and methods but also needs to promote higher-order thinking skills like CR, CT, and problem-solving [1]. These capabilities are needed in order for the students to be able to approach intricate scientific issues, innovate in the creation of experiments, and fit into the various challenges in today's world [2]. Since universities attempt to produce graduates who are not only informed but can also think independently and innovate, it becomes important to know the interaction between these mental skills and academic success.

CR in chemical education goes far beyond aesthetics; it includes having the capacity to create new ideas, think problems through from new angles, and synthesize information in new combinations [3]. Creative thinking allows learners to visualize abstract chemical occurrences, design unique experimental protocols, and suggest novel alternatives to scientific problems [4]. In B.Sc. chemistry courses, CR can result in increased motivation, deeper involvement with course content, and a higher likelihood of scientific discovery. Though acknowledged as important, however, CR is too often neglected within conventional curricula, which instead focus on rote memorization and procedural knowledge at the expense of imaginative and divergent thinking [5].

CT is systematic reasoning in which information is actively analyzed, synthesized, and evaluated in order to draw well-supported conclusions [6]. In chemistry, CTis essential in the interpretation of experiment data, evaluation of the credibility of scientific assertions, and decision-making within the laboratory. Strong CT abilities among students enable them to challenge assumptions, recognize inconsistencies in reasoning, and translate theoretical concepts to application [7]. Thus, the development of CT is important for academic achievement and in enabling students to make meaningful contributions to scientific research and industry.

Problem-solving is fundamental to chemistry, in which students are continually asked to use what they know to solve novel situations, diagnose experimental problems, and solve sophisticated theoretical dilemmas [8]. Problem-solving is facilitated by a blend of discipline-specific knowledge, logical thinking, and the capacity to translate learned material to novel situations [9]. The connection between problem-solving capacity and educational attainment has long been established in education research, with studies indicating that those students that perform well at problem-solving are likely to have better academic results [10]. Yet the means whereby problem-solving capacity affects academic performance, and to what degree it is promoted by existing pedagogical approaches, continue to be areas of research study [11].

The interchange among CR, CT, problem-solving capacity, and educational attainment is complex and dynamic [12]. Although every skill makes individual contributions to student growth, their overall impact can be synergistic in enhancing learning outcomes and developing a greater understanding of chemistry. Identification and cultivation of these skills in the undergraduate chemistry curriculum are thus of utmost significance. Further, the identification of appropriate teaching strategies that enhance these capabilities can guide curriculum development, instructional approaches, and methods of assessment in order to contribute to improved chemistry education [13].

Through the illumination of the interplay between CR, CT, problem-solving capacity, and academic success, this study hopes to provide useful insights to chemistry education. The results are anticipated to serve as information to educators, curriculum writers, and policy makers in informing the design of teaching strategies that not only maximize academic achievement but also equip students with the intellectual capabilities essential to succeed in professional scientific careers in the 21st century.

1.2 Problem statement

Despite the critical significance of problem-solving, CT, and CR skills in achieving chemistry mastery, numerous B.Sc. students do not efficiently develop and utilize these skills, which can impede their educational attainment as well as their overall scientific ability. Conventional teaching approaches tend to favor memorization and procedural knowledge at the expense of developing higher-order thinking skills, creating a discrepancy between students' potential and actual academic performance in chemistry courses [14]. In addition, the degree to which CR, CT, and problem-solving skills contribute to success in chemistry is under-researched, and there is no clear consensus about optimal pedagogical approaches to developing these skills. This study aims to address these issues by examining levels of these cognitive skills among B.Sc. chemistry students, investigating their correlation with educational attainment, and determining instruction strategies that work effectively to enhance these key skills, hence bringing about enhanced learning outcomes and enhanced student readiness for professional scientific careers.

1.3 Significance of the study

This research is important in that it closes an essential loop in chemistry education by investigating how CT, PSA, and CR help B.Sc. students achieve better in their studies. By establishing the links between these cognitive abilities and student performance, the study provides useful information that can inform educators who aim to maximize learning outcomes and prepare students better for the challenges in scientific professions. The results can be used to inform the design of more impactful teaching practices that transcend rote learning and facilitate higher-order thinking, ultimately enabling the development of innovative, analytical, and flexible graduates. This contribution is necessary not just to further the discipline of chemistry education but also to prepare students with the competencies needed to thrive in an increasingly complicated and dynamic scientific world.

1.4 Objective of the study

- To determine the levels of CR, CT, and problem-solving skills among B.Sc. chemistry students.
- To analyze the association between CR, problem-solving skills, and CT and academic performance in chemistry.
- To determine the impact of CR and CT ability of students on the academic performance in chemistry classes.
- To find out effectual teaching methodologies that promote CR, CT, and problem-solving skills for B.Sc. chemistry students.

1.5 Research Questions

1. What are the levels of CR, CT, and PSA among B.Sc. chemistry students?
2. To what extent do CR and CT abilities impact the academic performance of chemistry students in their classes?

1.6 Research Hypothesis

H1: There is significant variation in the levels of CR, CT and problem-solving skills among chemistry students

$H1_0$: There is no significant variation in the levels of CR, CT and problem-solving skills among chemistry students

H2: There is significant associations among CR, PSA, CT and academic achievement of students

$H2_0$: There is no significant associations among CR, PSA, CT and academic achievement of students

H3: There is significant impact of of CR and CT ability of students on the academic performance in chemistry classes

$H3_0$: There is no significant impact of of CR and CT ability of students on the academic performance in chemistry classes

H4: Diverse teaching methodologies promote CR, CT, and PSA for B.Sc. chemistry students.

$H4_0$: Diverse teaching methodologies do not promote CR, CT, and PSA for B.Sc. chemistry students.

1.7 Paper organization

Section 1 describes the significance, aim, and problems that are found in the study of knowledge about the concepts of CR, CT, PSA and student academic achievement. Previous studies related to the current research and knowledge gaps are described in Section 2. Section 3 describes the research approach, i.e., the research site, research design, research tool, and quantitative analysis of the study. The results of the study are laid out in Section 4. Section 5 talks about the discussion part of the study, and Section 6 is the conclusion and implications of the study.

2 Literature Review

The prevalent study [15] investigated the effect of collaborative teaching approach on Academic Achievement of Basic Students of different cognitive types in Basic Science. The study employed the quasi-experimental research design of pre-test post-test control group. Basic Science Performance Test (BSPT) and Group Embedded Figure Test (GEFT) were utilized as research instruments. Four experts validated the instruments, BSPT. Purposive sample of 4 schools encompassing 159 students from 4 intact classes constitute the sample. The findings of the research showed that the students who were taught Basic Science under collaborative teaching strategy scored better than those students taught under the traditional method. There is significant variation between the mean score of performance of field-independent cognitive style students who learned Basic Science with collaborative teaching strategy and those students who learned with traditional teaching strategy. There is significant difference between mean score of performance of field-dependent cognitive style students who were taught Basic Science with collaborative strategy and those who were taught with traditional teaching strategy.

The conventional research [16] proposed that EFs abilities are needed to reach success in life as well as in school life. The experts and educationists coined EFs in numerous terms and recognized the crucial constructs of EFs. They include cognitive flexibility, working memory, inhibition, attention, emotional control, etc. In this chapter, the definition and various definitions of EF with its elements are highlighted. The result concluded that EFs, such as working memory, cognitive flexibility, attention, and inhibition, are a precondition for academic achievement, from preschool through to higher education. The brain's role in executive functioning, particularly the areas or sections in the brain responsible for effective executive functioning skills. The results show that individuals with high EFs were reported to have better academic performance compared to those with low EFs, and there's high correlation between EFs and academic performance. In addition to teaching what to learn, teachers need to include EFs in transacting the curriculum.

The earlier study [17] uses quasi non-equivalent, non-randomized factorial design, explored the attitude of Chemistry students towards chemistry and academic performance among second year Bachelor of Education students who were instructed through the flipped classroom method. Pre-attitude test of 30-items questionnaire was allotted in the sample study of 100 students to determine students' attitude towards chemistry. Pre-test was also allotted to experimental and control group. This was then followed by teaching using flipped classroom method and experimental group was taught with traditional method. Experimental group as well as control group was administered post-test. Post-attitude outcome showed a very high mean in comparison to pre attitude score. The result of analysis by sample t-test showed students having positive attitude towards chemistry, when they were taught with flipped classroom. The results of the research in academic achievement revealed that the academic achievement of students was considerably higher than that of the control group. The implication of the above results is that flipped classroom method could improve student attitudes towards chemistry and therefore improve their academic performance.

The major aim of the research [18] was to compare the method of instruction and to enhance CT amongst nursing students. Pre-test and post-test control group design was used. B.Sc Nursing III year students were taken as experimental group and comparison group. Experimental group and comparison group were assessed for the CT skill in structured questionnaire. The McMurray's method scoring criteria were used in scoring concept maps. The findings of the study reveal that the pre-test and post-test average knowledge scores in Concept mapping were significantly higher than traditional group at 0.05 level.

The current research [19] states the impact of Creative-Teaching strategy on abstract creative-thinking ability in elementary science was determined with the application of pretest and posttest quasi experimental study. Torrance Test of Creative Thinking tool was employed in data collection. Results indicated that there is no significant variation in the ACT between diverse-ability students under the teaching methods. The students instructed with Basic Science through CT showed significantly higher ACS than those instructed through Lecture Method. There were no significant difference found in the ACS of the students according to gender, respectively. Conclusion: ACT among diverse-ability students was developed without gender variation, if Basic Science is instructed with Creative Teaching.

The recent study [20] shows The impact of Creative-Teaching (CT) on Creative-Thinking-Elaboration (CTE) of various-ability upper-basic science students in Gboko was explored with a pre-test and post-test quasi-experimental design. The findings revealed no statistical difference in the CTE between various-ability students in the teaching approaches. Though, students taught Basic Science with CT scored far more CTE compared to those in the Lecture Method. There was no significant difference in the CTE of students based on gender. From the results, it was inferred that CT promotes students' CTE without gender bias and hence it is advisable to use it in teaching science in basic schools.

The study [21] examined the impact of science and technology self-efficacy, learning styles, and emotional intelligence on science achievement. Ninety-one pre-service science teachers enrolled in the B. Sc. Science. The major findings of this study were that the study highlights the central role of STEM field self-efficacy, particularly among males, stresses the importance of cultivating confidence in the STEM field, and finds a correlation between emotional intelligence and academic achievement among pre-service science teachers.

The current study [22] was aimed at identifying whether there exists a correlation between school internal factors and their impact on students' academic achievement in science subjects at the secondary school level in Punjab. A quantitative survey approach was adopted, and a self-administered questionnaire was used to gather data for school internal factors, such as laboratories, curriculum, and teacher quality, and students' science academic achievement. The research summarizes that it is vital to improve the resourcefulness of science teachers through the provision of science teaching and learning support materials. These materials allow students to conduct experimental learning, acquire CT, and seek innovative problem-solving approaches. Additionally, the report highlights the need for frequent review and content updating of the secondary school curriculum to meet its quality standards. The hiring of qualified teachers holding higher degrees in the respective disciplines and providing continued professional development for teachers is also suggested to enhance science academic achievements.

The study [23] was conducted to establish if there are learning styles and pedagogies which are determinants of effective learning. Instruments used for data collection were the chemistry achievement test and the chemistry learning style questionnaire. Data analysis involved the use of the use of mean and independent sample t-tests. The findings revealed that there was a huge difference in the performance of students instructed through the puzzle teaching strategy group and those instructed through the lecture style and learning styles with teaching method and sex do not affect students' outcomes. It was determined that learning styles and corresponding teaching methods are determiners of students' performance, and teachers were therefore advised to utilize methods with the same characteristics as students' learning styles.

2.1 Research Gap

Though available literature is rich in the contribution of CR, CT, and problem-solving to science education, there is a lack of research aimed at B.Sc. chemistry students at undergraduate level in particular. The majority of the studies are on secondary school or other fields, and the few that consider all three cognitive abilities at once are also not focused on higher education chemistry. In addition, there is sparse empirical data available on the effectiveness of particular methods of teaching to adoptive these skills in students studying B.Sc. chemistry. This deficiency reinforces the requirement for focused research to not only measure CR, CT, and problem-solving skills in B.Sc. chemistry students but also investigates their combined effect on performance in academic work and discovers pedagogical measures most appropriate to develop these critical skills in undergraduate chemistry education.

3. Research Methodology

The research design is to carry out various processes, such as instruments and procedure to gather data for the research objective. An appropriately designed research is necessary to achieve reliable and valid results. It includes the right way of approach for the current study by responding the questions [24]. In this study, a quantitative research approach was adopted, as it is particularly suitable for measuring the perceptions of 600 B.Sc. chemistry students and examining predicted outcomes using statistical techniques. Quantitative research yields reliable and factual result data which can be generalized to some larger sample population and allows to understand the opinion of the students [25].

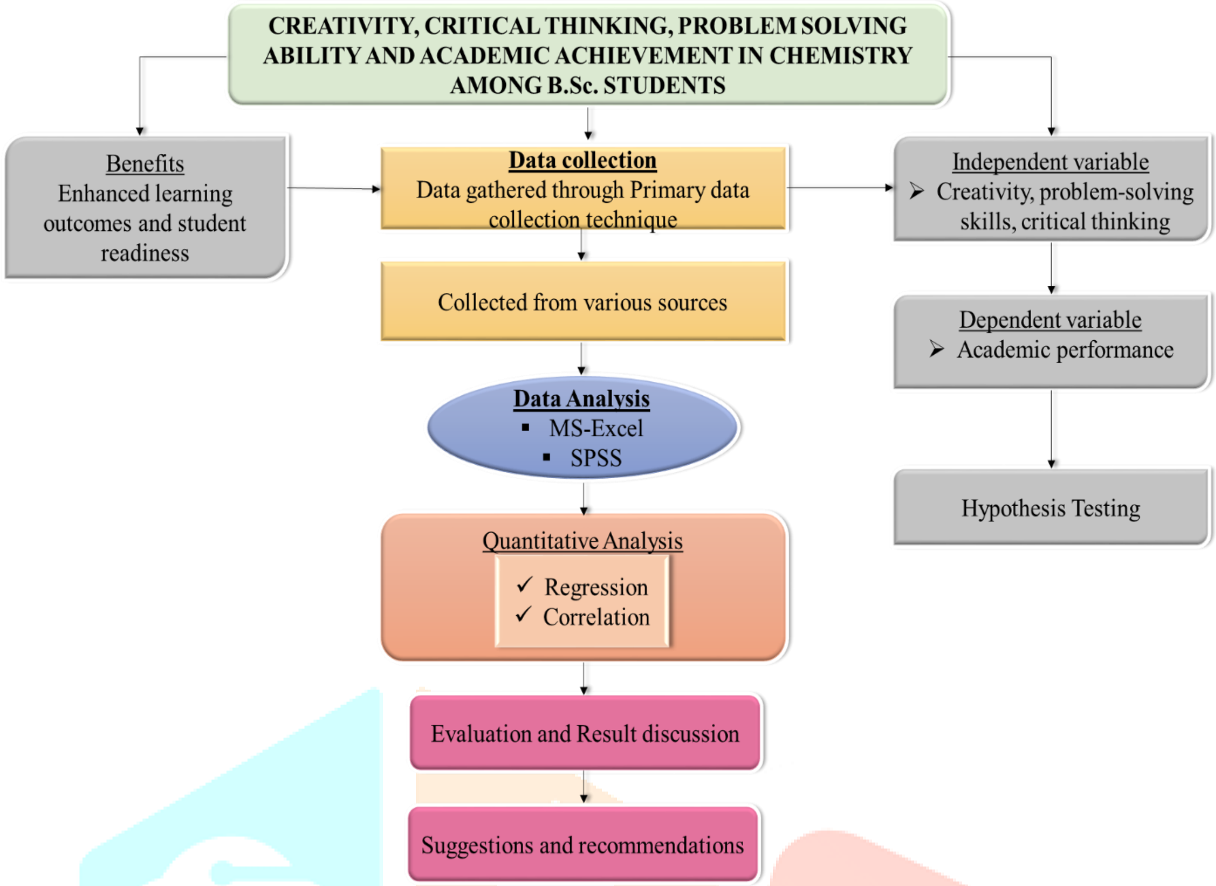


Figure 1. Research Designs

Figure 1 exemplifies the research framework of the present study. The tables and figure reveals the statistical results of the various analysis such as regression and correlation. The tests are conducted to evaluate the hypothesis of the current research.

This research was conducted among B.Sc chemistry students in India, with participants selected through a purposive sampling method to ensure representativeness and minimize bias [26]. The sample size must be designated carefully to achieve the accurate consequence [27]. A total of 600 students from first, second and third year participated in the study, ensuring that the data collected would be sufficient to meet the research objectives and provide meaningful insights into CR, CT and PSA among this population.

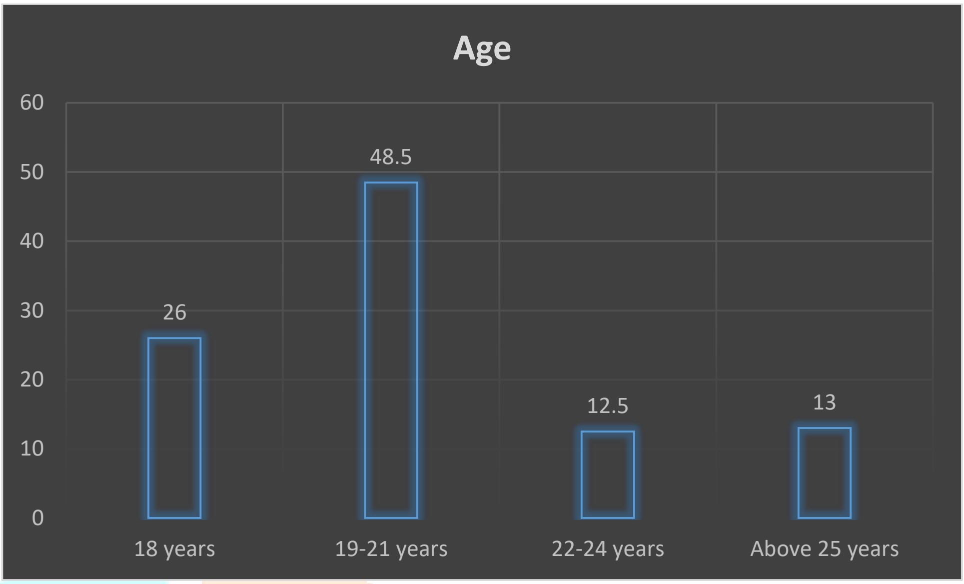
Data collection was carried out using a structured questionnaire developed based on the study variables and research questions. The questionnaire included Likert-scale items and multiple-choice questions to assess students' information regarding their academic achievements. Respondents who were willing and able to provide accurate responses were included to ensure data quality and reliability. The data collection process is a main phase in the research, affecting the quality of results through reducing potential errors that might arise during the research [28].

Quantitative method is one of the research method, which involves arithmetical data accumulation and examines the data employed for research purpose as well as hypothesis analysis. Quantitative method assists in exercising influences, preparations and inferences on a sample meant for calculating and scheming the variables. In this study, the quantitative method involved the use of structured questionnaires, and the collected data were analyzed using the SPSS software tool. The data were exported into Excel sheets to facilitate the organization and examination of study variables. SPSS was chosen for its efficiency, user-friendly interface, and robust statistical capabilities, which support the accurate analysis and interpretation of quantitative data. The SPSS software is used for analysis of the data by researchers in various sectors, including education, due to its reliability and ease of use [29].

4. Results

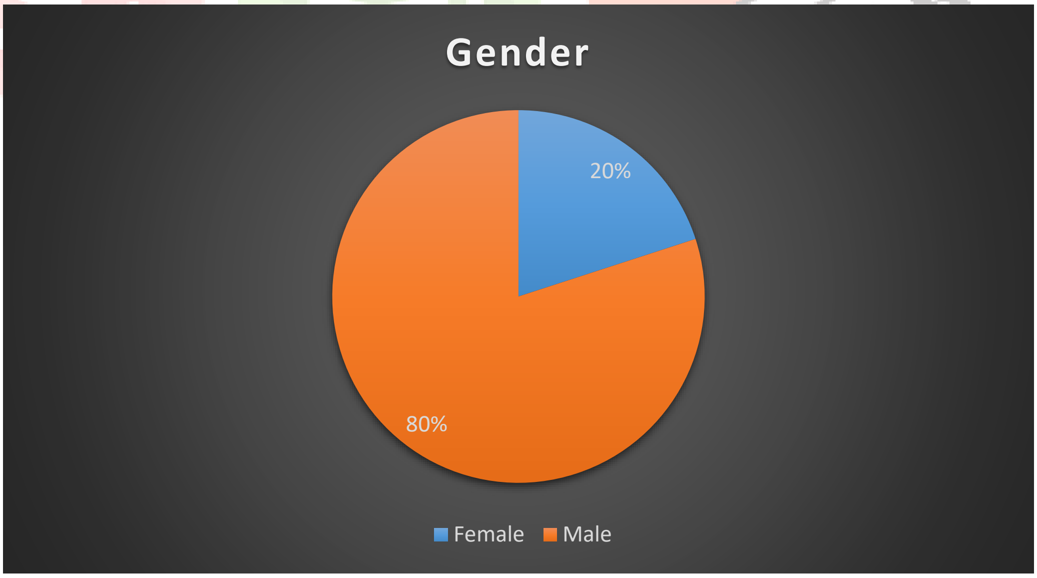
The demographic particulars of the participants are illustrated below:

Age



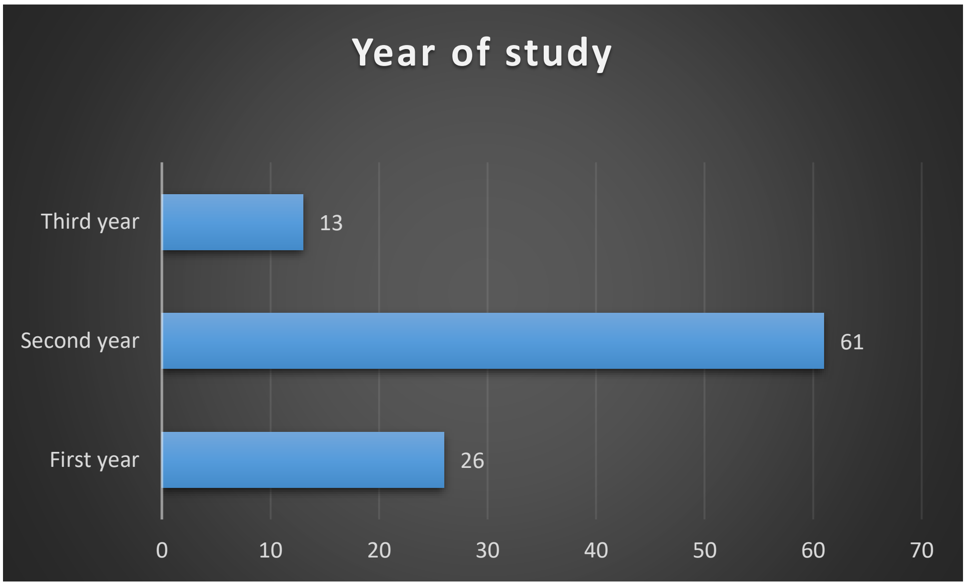
According to demographic information, most of the B.Sc. chemistry students covered in this study belong to the 19-21 years category with 48.5%, while 26% of the respondents are 18 years old. The age groups 22-24 and over 25 years represent 12.5% and 13% of respondents, respectively.

Gender



In gender terms, there is also a preponderance, with 80% of the sample composed of male students and only 20% made up of female students, which indicates a wide gender disparity in B.Sc. chemistry intake.

Year of study



The majority of participants are in the usual age group for undergraduate study, with some smaller percentage of older students perhaps coming back to education or studying at a different pace. The majority of students (61%) are in their second year, 26% are first-year, and 13% are in their third year. This sampling assumes that the sample is largely made up of students who have already done a minimum of a year in their chemistry course, which can affect their levels of CR, CT, and problem-solving ability because of higher levels of academic exposure and experience.

Statistical Analysis

Table 1 Reliability Statistics	
Cronbach's α	N
.990	30

The attained Cα value is 0.990, indicating that the used data are very reliable and the model is very good fit. The value above 0.7 is taken as acceptable. Therefore, it reveals the higher internal consistent within the dataset and the research includes certain sample.

Hypothesis 1

Table 2 Descriptive Statistics					
	N	Min	Max	Mn	SD
CR: I often find new and unique ways to solve chemistry problems.	600	1	5	2.23	1.267
I enjoy thinking of alternative explanations for chemical phenomena.	600	1	5	2.32	1.006

I can easily generate multiple ideas when faced with a chemistry assignment.	600	1	5	2.32	1.006
I like to connect chemistry concepts to real-world situations in innovative ways.	600	1	4	2.26	.859
I am comfortable proposing unconventional solutions during lab work.	600	1	5	2.23	1.267
CT:I critically evaluate the information before accepting it as fact in chemistry lessons.	600	1	5	2.17	1.253
I critically evaluate the information before accepting it as fact in chemistry lessons.	600	1	4	2.19	.762
I reflect on my mistakes in chemistry to improve my understanding.	600	1	4	2.26	.859
I question the validity of experimental results before drawing conclusions.	600	1	4	2.26	.859
I am able to analyze complex chemical problems by breaking them into smaller parts	600	1	5	2.36	1.424
PSA: I can systematically approach and solve unfamiliar chemistry problems.	600	1	5	2.30	1.326
I am confident in applying different strategies when my initial approach fails.	600	1	5	2.23	1.267
I persist until I find a solution to challenging chemistry tasks.	600	1	5	2.30	1.326
I use logical reasoning to solve chemistry problems.	600	1	5	2.30	1.326

I can transfer knowledge from one chemistry topic to solve problems in another	600	1	5	2.30	1.326

The descriptive statistical analysis of CR, CT, and problem-solving skills of B.Sc. chemistry students indicates evident variation in their levels. Mean scores for CR questions are 2.23 to 2.32, for CT from 2.17 to 2.36, and for problem-solving competence from 2.23 to 2.30, with standard deviations reflecting a moderate range of responses. These findings indicate that although the students rate themselves slightly below the midpoint, there are significant differences in how they view their strengths across the three areas. The difference in mean scores, as aided by the variability expressed through the standard deviations, furnishes proof of meaningful differences in the levels of the students' CR, CT, and PSA. Thus, these results validate the hypothesis that there is considerable difference in the levels of CR, CT, and problem-solving ability among B.Sc. chemistry students.

Hence, H1: There is significant variation in the levels of CR, CT and problem-solving skills among chemistry students has been proved from the above analysis.

Hypothesis 2

Correlation Analysis

Table 3 Correlations

		My creative thinking helps me achieve higher grades in chemistry.	My ability to solve problems effectively contributes to my academic success in chemistry.	I believe that CT is essential for excelling in chemistry exams.	There is a strong link between my creative ideas and my performance in chemistry projects.	Students who demonstrate strong problem-solving skills generally perform better in chemistry assessments
My creative thinking helps me achieve higher grades in chemistry.	Cr	1	.963**	1.000**	1.000**	1.000**
	S		.000	.000	.000	.000
	N	600	600	600	600	600
My ability to solve problems effectively contributes to my academic success in chemistry.	Cr	.963**	1	.963**	.963**	.963**
	S	.000		.000	.000	.000
	N	600	600	600	600	600
I believe that CT is essential for excelling in chemistry exams.	Cr	1.000**	.963**	1	1.000**	1.000**
	S	.000	.000		.000	.000
	N	600	600	600	600	600
	Cr	1.000**	.963**	1.000**	1	1.000**

There is a strong link between my creative ideas and my performance in chemistry projects.	S	.000	.000	.000		.000
	N	600	600	600	600	600
Students who demonstrate strong problem-solving skills generally perform better in chemistry assessments	Cr	1.000**	.963**	1.000**	1.000**	1
	S	.000	.000	.000	.000	
	N	600	600	600	600	600

The second hypothesis is strongly supported by the correlation analysis, which posits that there are some correlations between CR, problem-solving skills, CT, and achievements in chemistry. The Pearson correlation coefficients among the items for these constructs are very high at 0.963-1.000, all of which are significant at the 0.01 level ($p < 0.01$). This shows a highly positive correlation between students' views of their creative thinking, problem-solving capacity, and CT, and their academic performance in chemistry. To put it another way, students who evaluate themselves high in CR, problem-solving, and CT are those who also score higher on academic achievement in chemistry. These findings offer unequivocal statistical proof in support of the hypothesis that these cognitive abilities are highly and positively correlated with students' performance in chemistry courses.

Hence, H2: There is significant associations among CR, problem-solving skills, CT and academic achievement of students has been proved from the above analysis.

Hypothesis 3

Regression analysis

Table 4 Model

Model	R	R^2	Adj. R^2	SE
1	.958[a]	.918	.918	.363

Table 5 Coefficients[a]

Model		Unstd Coeff		Std Coeff		
		B	SE		t	Sig.
1	(Constant)	.216	.046		4.712	.000
	I often use creative strategies to improve my chemistry grades.	-.064	.026	-.051	-2.487	.013
	My CT skills have a positive impact on my test performance in chemistry	.203	.086	.229	2.357	.019
	I believe creative students tend to understand chemistry concepts more deeply	.731	.084	.765	8.650	.000

a. Dependent Variable: Teachers recognize students with high CR and CT as top performers in chemistry

The regression analysis provides strong evidence in support of the third hypothesis, which posits that CR and CT abilities significantly impact students' academic performance in chemistry classes. The model summary shows a very high R value of 0.958 and an R Square of 0.918, indicating that approximately 91.8% of the variance in the dependent variable teachers recognizing students with high CR and CT as top performers in chemistry can be explained by the predictors: creative strategies, CT skills, and the belief that creative students understand chemistry concepts more deeply. All three predictors are statistically significant ($p < 0.05$). Notably, the belief that creative students tend to understand chemistry concepts more deeply has the strongest positive impact (Beta = 0.765, t = 8.650, p = 0.000), highlighting its substantial influence on academic recognition. The use of creative strategies has a small but significant negative coefficient (Beta = -0.051, t = -2.487, p = 0.013), suggesting that while CR is important, not all creative strategies may directly translate to recognition by teachers. Meanwhile, CT skills have a significant positive effect (Beta = 0.229, t = 2.357, p = 0.019), further supporting the hypothesis.

Overall, these results confirm that both CR and CT abilities play a significant and positive role in students' academic performance and recognition in chemistry, thus proving the hypothesis.

Hence, H3: There is significant impact of of CR and CT ability of students on the academic performance in chemistry classes has been proved from the above analysis.

Hypothesis 4

Correlation Analysis

Table 6 Correlations

		Project-based learning activities in my chemistry classes enhance my creative thinking.	Group discussions and debates in chemistry lessons improve my CT skills.	Problem-based learning tasks help me develop better PSA.	The use of real-life case studies in chemistry classes encourages me to think creatively.	Inquiry-based experiments in the laboratory foster my CT and problem-solving skills
Project-based learning activities in my chemistry classes enhance my creative thinking.	Cr	1	.985**	.985**	.707**	.979**
	S		.000	.000	.000	.000
	N	600	600	600	600	600
Group discussions and debates in chemistry lessons improve my CT skills.	Cr	.985**	1	1.000**	.684**	.993**
	S	.000		.000	.000	.000
	N	600	600	600	600	600
Problem-based learning tasks help me develop better PSA.	Cr	.985**	1.000**	1	.684**	.993**
	S	.000	.000		.000	.000
	N	600	600	600	600	600

The use of real-life case studies in chemistry classes encourages me to think creatively.	Cr	.707**	.684**	.684**	1	.679**
	S	.000	.000	.000		.000
	N	600	600	600	600	600
Inquiry-based experiments in the laboratory foster my CT and problem-solving skills	Cr	.979**	.993**	.993**	.679**	1
	S	.000	.000	.000	.000	
	N	600	600	600	600	600

The correlation analysis strongly supports Hypothesis 4, according to which various teaching approaches are conducive to improving CR, CT, and problem-solving skills of B.Sc. chemistry students. Pearson correlation coefficients between different teaching methods such as project-based learning, group discussions, problem-based learning, real-life case studies, and inquiry-based experiments and the enhancement of cognitive skills are all high and statistically significant at the 0.01 level. For example, project-based learning has extremely high positive correlations with group discussions (r = 0.985), problem-based learning (r = 0.985), and inquiry-based experiments (r = 0.979) but also with the utilization of real-life case studies (r = 0.707). Likewise, group discussions and problem-based learning are uncannily correlated (r = 1.000), and the two of them are highly correlated with inquiry-based experiments (r = 0.993). These findings suggest that the students who think one innovative teaching style is good for their cognitive ability development are highly likely to experience the same advantages of such benefits from other active and inquiry-oriented techniques.

Hence H4: Diverse teaching methodologies promote CR, CT, and problem-solving skills for B.Sc. chemistry students has been proved from the above analysis.

5. Discussion

The current research aimed to identify the levels of CR, CT, and problem-solving ability in B.Sc. chemistry students, and to study the relationships between these cognitive skills and academic performance and their relation with different teaching methodologies. Results provide significant understanding of the cognitive profile of undergraduate chemistry education and are fully consistent with the current literature.

Descriptive statistics indicated that B.Sc. chemistry students scored themselves in the middle on CR, CT, and problem-solving skills, with mean values for each measure slightly below the neutral midpoint. Nonetheless, the analysis also showed considerable variability between these skills, as students see differences in their own cognitive abilities. This result aligns with [15], who had previously indicated that students have varied cognitive styles and capabilities that can affect their performance in academics. That there is a moderate range in the responses also indicates that although there are some students who are confident of their creative and analysis skills, others might need extra support in order to acquire these critical skills.

The research identified extremely strong and statistically significant relationships between CR, CT, problem-solving ability, and chemistry academic performance. The students who indicated higher scores on these intellectual abilities also showed a trend toward better academic performance. This finding is consistent with the research by [16], who also highlighted the role of executive functions like cognitive flexibility and working memory in academic achievement. Likewise, the results are supported by [17], who noted that students with positive attitudes and higher-order thinking skills were more successful academically when subjected to creative teaching methods. Collectively, these results support the idea that CR, CT, and problem-solving are not just helpful but necessary for learning chemistry.

Regression analysis also validated that CR and CT skills have a significant influence on the academic performance of students in chemistry classes. The supposition that creative students grasp chemistry concepts better came out as the most powerful predictor of academic distinction, with CT skills also having a strong positive influence. This is in agreement with the findings of [18], whose work showed that new teaching methodologies, like concept mapping, significantly improve CT and, by extension, performance. The results point to the need to develop such cognitive skills to help students achieve success and awards in the academic environment.

The correlation analysis of the study furnished strong evidence that varied teaching approaches like project-based learning, group discussions, problem-based learning, real-life case studies, and inquiry-based experiments are highly correlated with the development of CR, CT, and PSA. These findings are in agreement with the literature, such as research by [19], which established that creative teaching strategies develop significantly higher abstract creative-thinking abilities of students without gender bias. The direct impact of new teaching strategies is also supported by [21], pointed out the significance of resourceful and student-centered teaching methods for the enhancement of higher-order cognitive abilities and better academic achievements in science education.

The blending of research in this research and the literature reveals the ultimate necessity for chemistry teachers to transcend the use of traditional, lecture-oriented instruction. Rather, employing a range of active, inquiry-directed, and cooperative teaching approaches can successfully adopt the intellectual skills upon which academic success is based. In addition, acknowledging student diversity in cognitive capacities and being able to offer support specifically targeted at it can address gaps and ensure that all students have a chance to succeed.

6. Limitations

The population for this research consisted only of B.Sc. chemistry students in a single geographic location, which might restrict the applicability of the results to other fields of study. The research also failed to control for possible confounding factors like students' earlier academic performance, socio-economic status, or educational resources availability, all of which might affect the development of cognitive skills and academic performance. The study also solely used quantitative survey data, which is good for statistical analysis but fails to provide the rich views and lived experiences of the students towards various teaching approaches.

7. Conclusion

The present study exposes the key roles played by CR, CT, and problem-solving skills in B.Sc. chemistry students' academic achievement, showing that these intellectual capacities are intimately related and heavily impacted by varied teaching styles. The results underpin the need to shift away from conventional lecturing and embrace novel, student-centered ways to develop higher-order thinking abilities in undergraduate science education. Theoretically, this study adds to existing knowledge on cognitive skill construction in university education, in support of constructivist and inquiry-based learning theory integration. In practice, the findings imply that teachers and curriculum developers need to emphasize active learning approaches like project-based learning and experimental inquiry-based learning to increase students' engagement and learning performance. Future research is suggested to take the study to various disciplines and locations, include longitudinal and qualitative approaches to bring out richer insights, and study the influence of other variables like motivation, past achievement, and socio-economic status. Such studies will contribute further to effective pedagogical practices and to the overall development of students' cognitive potential in science education.

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