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IMPACT OF CREATIVITY AND CRITICAL THINKING ON CHEMISTRY AT THE HIGHER EDUCATION LEVEL

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Abstract: This study explores the significant influence of creativity and critical thinking on the pursuit of chemistry education at the higher academic level. With the rapidly changing landscape of scientific inquiry and the demand for innovative problem-solving, nurturing these cognitive skills has become crucial for aspiring chemists. The research aims to examine the correlation between creativity, critical thinking, and academic accomplishment in higher education chemistry courses by examining how these cognitive abilities influence students' ability to comprehend and apply complex chemical principles to real-world scenarios. Through a comprehensive methodology, including surveys, assessments, and qualitative analysis, the study seeks to identify the factors that facilitate or hinder the development of Creativity and Critical Thinking (CCT) among undergraduate chemistry students. By unravelling the intricate relationship between creative, critical thinking, and chemistry education, this research aims to provide valuable insights for educators, curriculum developers, and policymakers. The outcomes of this study hold significant implications for higher education pedagogy, inspiring transformative teaching approaches that foster creative thinking and analytical skills in students. Equipping the next generation ofchemists with these essential cognitive tools can pave the way for innovative scientific contributions and empower them to address the pressing challenges of the future with ingenuity and confidence. Ultimately, this research aspires to advance higher education in chemistry by cultivating a dynamic learning environment that nurtures intellectual curiosity and critical inquiry, positioning students for success in their academic journeys and professional careers. This research study utilized ANOVA with Cochran's test, intraclass correlation coefficient, descriptive statistics, correlation analysis, regression analysis, and LSD post hoc test to analyze a dataset with 741 participants across multiple variables. The results indicated significant variability between subjects, some variability between items, and a considerable amount of unexplained variability. However, the interaction effects and some individual predictors did not show significant effects on LA. Overall, the study provides valuable insights into the relationships between variables and their impact on academic achievement.

Keywords: Creative Thinking Skill, Critical Thinking, Higher Education Level, Students' Cognition, Problem-Based Learning, Academic Achievement.

1. INTRODUCTION

Critical Thinking (CT) encompasses abilities and attitudes closely linked to learning, self-directedness, critical analysis, and academic achievement [1]. In the rapidly evolving landscape of the 21st century, the significance of fundamental and creative thinking skills cannot be underestimated [2]. While traditional education has traditionally focused on imparting theoretical knowledge, the contemporary approach is shifting toward equipping students with transferable skills. These skills are essential not only for personal development but also for success in future careers, particularly in the field of chemistry [3]. To achieve this, educators play a crucial role in encouraging students to think critically about chemical concepts and theories [4]. The adoption of models such as Issue-Based Learning and Inquiry Models has been a common practice to enhance students' critical reasoning abilities and self-efficacy in pre-professional science education. However, during implementation, certain drawbacks emerged [5]. These drawbacks included the need to further enhance students' self-efficacy and refine the investigative process, with a particular emphasis on science process skills. In light of these considerations, this study aimed to assess the effectiveness of the Issue-Based Learning model in fostering students' critical reasoning abilities in the context of chemistry education [6]. The study followed a semi-experimental design, employing a post-test-only approach. The research group was exposed to the Problem-Based Learning (PBL) model, while the control group followed the conventional teaching model [7]. The students' responses were carefully analysed and measured as part of the evaluation process.

In the experimental class, the learning process commences with contextual problems designed to pique students' interest and motivate them to independently or collaboratively seek and design solutions [8]. The instrument employed in this study underwent prior validation by two experts in theory and materials. Notably, students in the experimental class exhibited superior critical thinking abilities compared to those in the conventional model [9]. The underlying principles of the overall senior optional school science educational program in 2018 (MoE, 2018) and the obligatory training science educational plan norms in 2022 (MoE, 2022) both emphasize core competencies in science, notably highlighting 'critical reasoning,' 'fundamental knowledge', 'logical thinking,' and 'fundamental inquiry' (Wei, 2020) [10]. Within the realm of science education, imagination and critical reasoning assume pivotal roles at the higher education level [11]. Fostering imagination among students opens doors to exploration, enabling them to delve deeply into laboratory work and beyond. Embracing creativity in the field of chemistry empowers students to challenge assumptions, recognize patterns, and make informed decisions in their scientific pursuits [12]. When higher education chemistry courses incorporate creativity and critical thinking, they not only facilitate a profound understanding of the subject but also enhance problem-solving skills. These attributes are highly valued in both industry and the scientific community, equipping students for real-world applications [13]. In the context of advanced chemistry education, nurturing creativity and critical thinking skills becomes paramount. By cultivating these qualities, students are better prepared to excel academically and professionally [14]. They can approach complex challenges with innovative solutions, and their capacity for critical thinking enables them to effectively analyze and address intricate problems [15]. The primary objective of this study is twofold: first, to assess the levels of creativity and critical thinking abilities among students, and second, to explore the relationship between students' critical thinking abilities and their academic grade levels. Ultimately, the integration of creativity and critical thinking in chemistry education lays the foundation for a new generation of innovative scientists and problem solvers who will make substantial contributions to the continually advancing world of science and technology.

2. LITERATURE SURVEY

Ismayilova *et al* [16] conducted this study to investigate college educators' perspectives on creative teaching and various factors that might influence academics' efforts to teach creatively in higher education. Furthermore, the findings demonstrate that, apart from personal characteristics such as creativity, the environment plays a significant role in facilitating creative teaching practices. Abouelenein *et al* [17] conducted a study that included semi-structured interviews, a survey scale for assessing scientific practice, and a computerized skill test during the investigation. The results indicated that the experimental group, who combined their regular science education with a Virtual Chemistry Laboratory (VCHL), exhibited advanced skills in scientific practices and digital proficiency. Contreras *et al* [18] proposed a framework consisting of objectives, developmental stages, key activities, key teams, stakeholders, drivers of change, expected outcomes, contingency plans, communication channels, impact assessment, budget structure, and a Gantt chart. The intention is to enhance students' understanding of how to conduct sound and creative research projects and develop research skills. Georgiou *et al* [19] contributed to this paper by advancing our understanding of how to support students' scientific education for responsible citizenship. They conducted a study that evaluated the impact of a learning intervention on biofuels, based on the Socio-Scientific Inquiry-Based Learning (SSIBL) instructional approach. The findings demonstrated that, after implementation, students in the SSIBL group outperformed their peers in the control group. Malik *et al* [20] designed this study to examine the effectiveness of the dialogic teaching model and the influence of orientation on critical thinking skills in leadership and motivation. According to the t-test results, students' critical thinking skills improved differently in the experimental and control groups. Additionally, gender did not affect the critical thinking abilities of students in the experimental group.

Bahtiar *et al* [21] initiated this research intending to draw inspiration from the data related to the essential skills that students should possess today, including collaboration, communication, critical thinking, and creative reasoning. Additionally, their findings indicated that male students exhibited superior communication and critical thinking skills compared to female students. Lv *et al* [22] proposed that the 4C capabilities displayed by female and male students are not significantly different. This research aims to investigate the relationship between critical thinking and the ripple effect on HR (Human Resources) professionals working within various industries. Suryono *et al* [23] designed this study to examine the impact of blended learning models on students' critical thinking skills, utilizing meta-analysis as the research method. The results revealed a moderate effect size of 0.79, indicating improvements in critical thinking abilities.

Febliza *et al* [24] conducted a study to compare students' critical thinking abilities using interactive media that catered to different learning preferences. Interactive videos on the colloid system and interactive web modules served as examples of such media. The outcomes demonstrated that interactive web modules were more effective in enhancing students' critical thinking skills compared to interactive videos. Hyytinen *et al* [25] explored the contributions of self-regulation and effort during test-taking to the overall performance of college students in critical thinking assessments. Their findings suggest that effort and time function as mediating variables, with self-regulation during test-taking indirectly affecting critical thinking performance task scores.

3. RESEARCH PROBLEM DEFINITION AND MOTIVATION

The research problem addressed in this study revolves around the exploration of the profound impact of Critical and Creative Thinking (CCT) on the study of chemistry at the higher education level. Chemistry, as a fundamental scientific discipline, plays a pivotal role in understanding the properties and interactions of matter, forming the foundation for various scientific advancements and industrial applications. With the ever-changing nature of scientific research, the need for creative solutions to complex problems has never been greater. Therefore, investigating the relationship between CCT in higher education chemistry courses and its impact on learning and academic performance is of utmost importance. The primary objective of this investigation is to examine how creativity, critical thinking, acquisition of chemical knowledge, and problem-solving skills interact within undergraduate chemistry courses. By comparing these cognitive abilities with students' capacity to apply theoretical concepts to real-world situations, the study aims to explore the implications of creative teaching approaches and critical thinking exercises in higher education chemistry courses. Additionally, this research seeks to identify potential obstacles or facilitators that may influence the development of creativity and Critical Thinking Skills (CTS) in chemistry education. The overarching goal of this research is to advance the field of chemistry education by creating an environment that nurtures innovation, encourages critical questioning, and cultivates transformative problem-solving skills among undergraduate students.

The motivation behind conducting this research is deeply rooted in the recognition of the indispensable role that Creativity and Critical Thinking Skills (CCT) play in shaping the landscape of higher education in chemistry. As the field of chemistry advances, it becomes increasingly evident that the mere memorization of facts and formulas falls short of addressing the complex challenges of contemporary science. With creativity taking a prominent position in the realm of chemistry, students are encouraged to think beyond conventional boundaries and devise innovative solutions to intricate chemical problems. Simultaneously, the development of Critical Thinking Skills (CTS) equips students with the capacity to effectively analyse, evaluate, and synthesize information, enabling them to differentiate scientific evidence from mere conjecture and gain a deeper understanding of fundamental chemical principles. The inquiry revolves around investigating the impact of these cognitive abilities on students' aptitude to translate theoretical knowledge into practical applications. The overarching goal of this study is to uncover the mechanisms through which creativity and CTS (critical thinking skills) can be nurtured and cultivated within the domain of chemistry. Furthermore, gaining insights into the development of these skills within higher education settings will empower educators and institutions to craft tailored interventions and teaching methodologies that foster and support the growth of CCT among chemistry students. Ultimately, this research aims to advance higher education by equipping students with the critical thinking and analytical skills requisite for them to emerge as chemists capable of innovation and problem-solving in the real-world contexts they will encounter in their careers.

4. RESEARCH PROPOSED METHODOLOGY

The purpose of this proposed research is to assess the impact of integrating CCT into higher education chemistry education. This study aims to investigate how the incorporation of innovative teaching approaches and the utilization of problem-solving techniques can enhance students' learning experiences and outcomes in higher education chemistry. The proposed research employs a mixed-method approach, combining quantitative assessments with qualitative feedback. The intervention's primary objective is to evaluate its effectiveness in enhancing students' critical thinking skills, self-efficacy, and overall creative thinking abilities. Through this comprehensive research, the study aims to gain valuable insights into the potential benefits of integrating creative and critical thinking into chemistry education, thereby contributing to the advancement of pedagogical approaches in higher education.

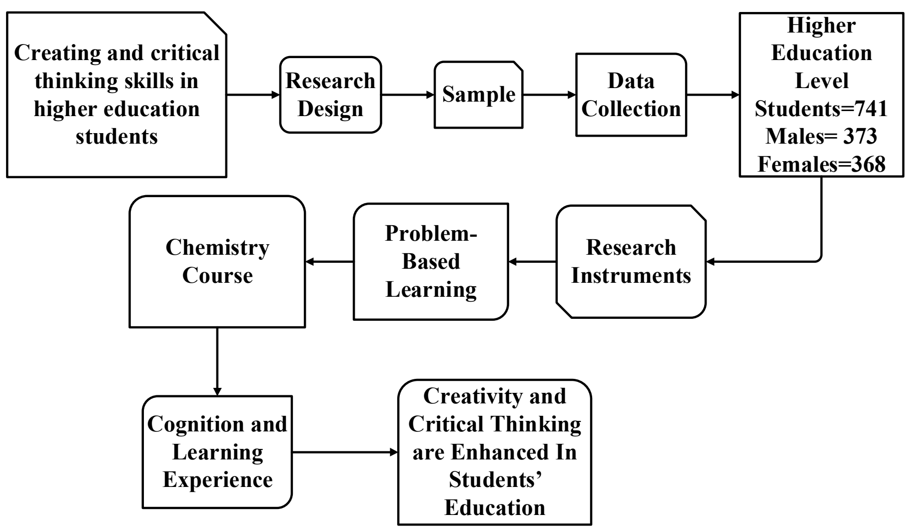

Figure 1: Block Diagram of the Proposed Work

Figure 1 presents a block diagram illustrating the relationship between creativity and Critical Thinking Skills (CTS) in Higher Education Students. The research design, as well as details about the proposed methodology and sample size, are depicted. Data collection for this study comprised the use of two primary instruments: a specifically designed test focusing on the Introduction to Chemistry course and an assessment of creativity. The study included 368 female participants, and

373 male participants, with a total of 741 students at the upper education level. The research investigated the impact of Problem-Based Learning (PBL) on the effectiveness of instructional interventions aimed at enhancing critical thinking skills in higher education. The findings suggest that improvements in students' critical thinking skills have a discernible impact on their cognitive development and learning outcomes, particularly in the context of chemistry courses. This enhanced focus on creativity and critical thinking is particularly notable in chemistry enrichment programs designed to elevate the quality of students' education.

4.1 Research Design

In an exploratory research design, researchers manipulate independent variables to observe their interactions with the dependent variable while controlling for other variables. For instance, in the context of an exploratory design, independent variables could include interventions aimed at fostering creativity and/or critical thinking in chemistry learning. Participants, who are chemistry students, are randomly assigned to one of two groups: a control group that receives traditional instruction and one or several experimental groups that undergo interventions designed to promote creativity or critical thinking. One experimental group might engage in problem-oriented learning activities that involve creative problem-solving, while another group might participate in a critical thinking workshop. In contrast, the control group receives standard chemistry instruction without these specific interventions. The research encompasses the examination of creativity, critical thinking, and academic performance, as well as pre-tests and post-tests.

4.1.1 Sample Study

The research study on creativity and critical thinking in university-level chemistry involved a diverse cohort of 741 undergraduate students hailing from various academic fields. This group of students, with ages ranging from 20 to 23, represents a dynamic and youthful segment of the higher education population. Among the participants, there were 368 female students, constituting approximately 49.6% of the total sample, and 373 male students, accounting for roughly 50.3% of the sample. This deliberate inclusion of students from diverse gender backgrounds and a range of academic disciplines contributes to the strength and generalizability of the study's findings. It offers a comprehensive insight into how creativity and critical thinking manifest among undergraduate students pursuing studies in chemistry and related fields.

4.2 Data Collection

The data collection process commenced with the administration of an introductory chemistry test and a creativity assessment at the outset of the study, involving all 741 participants to establish baseline levels. Subsequently, following the pre-test assessments, the intervention was implemented with the experimental group, while the control group received no intervention. Of the total participants, 368 were females, and 373 were males. Upon completion of the intervention, participants from both groups underwent post-test evaluations, which included the same introductory chemistry test and a creativity assessment. The post-test results were then compared to the pre-test results to evaluate the impact of the intervention on participants' knowledge and creativity.

4.2.1 Research Instruments

The learning tools employed in this study were meticulously crafted by educational professionals and chemistry professors, drawing upon evidence-based teaching techniques. These tools were thoughtfully designed to nurture critical thinking skills and bolster student's efficiencies. The learning tools were designed to support the specific learning objectives and topics included in the chemistry course of study, making them relevant and applicable to higher education. To validate the feasibility, usability, and efficacy of these learning tools, a pilot group of chemistry students participated in a feasibility test. Valuable feedback was gathered not only from the pilot group but also from instructors and educational professionals. This iterative feedback loop facilitated continuous refinement and optimization of the learning tools to ensure they served their intended purpose effectively. The feasibility test also examined the practicality of integrating these learning tools into the existing chemistry coursework. Factors such as time commitment, ease of use, and alignment with the curriculum were thoroughly assessed to gauge the suitability of these tools for incorporation across multiple chemistry classes. This feasibility test constituted a pivotal phase in the design and development of the learning tools, offering insights into their viability and their potential to enhance critical thinking and self-efficacy among higher education chemistry students. The favourable outcomes of the feasibility test have paved the way for the potential adoption of these study instruments within a broader educational community, promising to benefit a larger cohort of chemistry students.

4.3Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is an inquiry-based, student-centred approach to education that proves highly effective in nurturing creativity and critical thinking skills in higher education chemistry courses. In a PBL classroom, students tackle real-world chemistry problems that challenge their knowledge, analytical capabilities, and creative problem-solving skills. PBL entails active student participation, collaborative teamwork, research, and the generation of innovative solutions to intricate chemistry issues. It compels students to think critically, analyse data, and evaluate potential solutions, fostering higher-order thinking skills vital for chemistry problem-solving. Furthermore, PBL encourages students to consider problems from diverse perspectives, fostering creativity and innovation in their approach to problem-solving. This pedagogical approach creates an environment that empowers students to experiment and take risks, thereby encouraging them to think divergently and generate novel ideas. By incorporating PBL into the chemistry classroom, students not only enhance their comprehension of the subject matter but also cultivate essential critical thinking and creative problem-solving skills.

4.4 Chemistry Course and Assessing Creativity

In higher education, a chemistry course that prioritizes creativity and critical thinking transcends the conventional lecture-based approach, and it encompasses several key facets given as follows. Encouraging students to actively immerse themselves in the subject, delve into real-world applications, and cultivate problem-solving skills. Exploring historical discoveries and innovations in chemistry that demanded creative thinking. Nurturing a growth mindset among students to foster creativity throughout the learning process. Introducing students to innovative problem-solving techniques, including brainstorming, mind mapping, and lateral thinking. Teaching students how to design experiments with a focus on creativity and innovation. Incorporating inquiry-based experiments that prompt students to explore their research questions.Delving into interdisciplinary applications of chemistry, spanning fields such as biochemistry, materials science, and environmental chemistry. Proposing new and innovative applications of chemistry across various industries. Applying creative thinking to address environmental challenges, with an emphasis on green and sustainable chemical processes and product design. Equipping students with the skills to creatively and effectively communicate complex chemical concepts, including the use of visualizations, infographics, and multimedia presentations to convey scientific findings. This holistic approach to chemistry education empowers students to not only grasp foundational concepts but also to apply their creativity and critical thinking in diverse real-world scenarios, thereby preparing them for success in both academic and professional pursuits.

Assessment of creativity and critical thinking in a higher education chemistry course employs a range of formative and summative evaluation techniques. The objective is not solely to measure students' grasp of chemistry concepts but also to appraise their creative and critical thinking capabilities. Give open-ended assignments that ask students to come up with and develop their chemistry-related concepts. These assignments assess creativity, critical thinking, problem-solving skills, and the novelty of ideas generated. This evaluates students' capacity to critically analyze scientific literature and propose fresh insights. Assessments that challenge students to apply creativity and critical thinking to complex chemical problems. Collaborative problem-solving activities, brainstorming sessions, and creative presentations within group settings. These assess students' contributions, communication skills, and critical thinking in a team environment. The development of real-life chemistry case studies requires students to think critically and devise creative solutions for challenging problems. Participation in classroom discussions that encourage students to engage in critical reflection on various chemistry concepts, applications, and ethical considerations. Conducting peer-review sessions for creative assignments and research papers. This promotes peer-to-peer feedback, fostering ongoing learning and improvement. Evaluation of students' ability to clearly articulate creative ideas and effectively communicate complex chemical concepts to their peers. Incorporation of questions that assess students' comprehension of fundamental concepts and principles while challenging their critical thinking skills through higher-order thinking questions. These multifaceted assessment methods not only gauge students' knowledge of chemistry but also help nurture and evaluate their creative and critical thinking abilities, enhancing their overall readiness for real-world challenges in the field of chemistry and beyond.

5. EXPERIMENTATION AND RESULTS DISCUSSION

The experimentation and results discussion of this study investigates the influence of creativity and critical thinking on chemistry at the higher education level. This study delves into a crucial field of research that addresses the profound impact of cognitive abilities on students' learning experiences and academic performance in higher education chemistry. As higher education institutions increasingly emphasize the cultivation of creativity and critical thinking in students, this study aims to unveil their role in fostering problem-oriented approaches, scientific inquiry, and creative thinking within the context of higher education chemistry education. By examining the relationship between these cognitive skills and chemistry performance, this research seeks to provide valuable insights into the impact of creative and critical thinking education on the development of well-rounded chemists who are equipped to tackle real-world challenges and advance their scientific understanding of chemistry.

Table 1: Simulation System Configuration

SPSS Statistical Tool	Version 23.0
Operation System	Windows 10 Home
Memory Capacity	6GB DDR3
Processor	Intel Core i5 @ 3.5GHz

The Statistical Package for the Social Sciences (SPSS) software was used for the analysis of questionnaire data. A structured SPSS-based data collection was used for descriptive analysis, regression, and correlation analysis. The relationship between dependent and independent variables is estimated in the statistics model. Accordingly, the tools used to simulate the proposed system are presented in the following table 1.

Table 2: Reliability Statistics Analysis

Cronbach's Alpha	**No of Items**
.713	6

Table 2 displays reliability statistics, which are measures of the internal consistency of a scale (or questionnaire). In this particular case, the calculated Cronbach's alpha is 0.713, indicating a reasonably good value. This suggests that the six items on the scale exhibit moderate correlation with each other, signifying a satisfactory level of internal consistency. This implies that the items in the scale are measuring a similar construct or concept, and they are functioning effectively together as a reliable measurement tool.

Table 3:ANOVA with Cochran's Test Analysis

		Sum of Squares	df	Mean Square	Cochran's Q	Sig
Between People		31772.540	740	42.936		
Within People	Between Items	278.245	5	55.649	8.229	.144
	Residual	125002.089	3700	33.784		
	Total	125280.333	3705	33.814		
Total		157052.874	4445	35.332		
Grand Mean = 18.81						

Table 3 displays the ANOVA results with Cochran's Test, which provides information regarding the variability and significance of different sources of variability in the data. The "Between People" section in the ANOVA table offers insights into the variability among different subjects or participants in the study. The high values of both the sum of squares (31772.566) and the mean square (42.936) suggest significant variability among the study's subjects. Within People (Between Items)" section provides information about the variability among different items or subjects within the study. Cochran's Q (8.229) and its associated significance (SIG) (0.144) indicate some variability among the items, although it is not statistically significant at the conventional level ($p < 0.05$). The "Residual" section accounts for unexplained variability after controlling for the effects of other sources of variability.

Table 4: Intraclass Correlation Coefficient

Intraclass Correlation Coefficient							
	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.043[a]	.023	.066	1.271	740	3700	.000
Average Measures	.213[c]	.122	.298	1.271	740	3700	.000
Two-way mixed effects model where people effects are random and measures effects are fixed.							
a. The estimator is the same, whether the interaction effect is present or not.							

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.
c. This estimate is computed assuming the interaction effect is absent because it is not estimable otherwise.

Table 4 presents the Intraclass Correlation Coefficient (ICC), a statistical measure used to assess the consistency and agreement of individual measurements or ratings obtained from different raters or on different occasions. The calculated F-statistic is 1.271, with degrees of freedom (df1 = 740 and df2 = 3700). The associated p-value (SIG) for the F test is 0.000, indicating statistical significance.The Single Measures Correlation Coefficient (SCC) is a reflection of the consistency and agreement of individual measurements taken by different raters or on different occasions. In this context, the ICC value of 0.043 suggests that approximately 4.3% of the total variability in the measurements can be attributed to true differences between individuals.The calculated F-statistic remains at 1.271, with df1 = 740 and df2 = 3700, and the p-value (Sig) for the F test remains at 0.000, indicating statistical significance. This underscores that the Mean of the Average Measures ICC (AMIC) is statistically significant.The Mean of the AMIC serves as an evaluation of the agreement or reliability of average measurements derived from various raters or on different occasions. Higher ICC values indicate stronger agreement or reliability between measurements, whereas lower ICC values suggest greater variability and reduced agreement among measurements.

Table 5: Descriptive Statistics Analysis

	N	**Range**	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**	**Variance**
	Statistic	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**	**Statistic**
CTS	741	25	7	32	18.69	.223	6.079	36.954
CT	741	32	0	32	18.43	.221	6.009	36.110
SE	741	29	5	34	18.94	.217	5.919	35.039
SC	741	27	4	31	18.62	.210	5.723	32.756
LE	741	25	7	32	19.14	.215	5.852	34.246
LA	741	54	0	54	19.02	.223	6.062	36.753

Valid N (listwise)	741							

Table 5 presents the descriptive statistics results from the collected 741 participants for six variables: CTS, CT, SE, SC, LE, and LA. The 'Range' column illustrates the difference between the highest and lowest values observed for each variable. The range for CTS is 25, with a minimum score of 7 and a maximum score of 32. The 'Minimum' and 'Maximum' columns indicate the lowest and highest values recorded for each variable in the dataset. For instance, the CT variable has a minimum value of 0 and a maximum value of 32. The 'Mean' column displays the average value for each variable. In this study, the average CTS score is approximately 18.69. Finally, the "Std." column represents the degree of variability or dispersion in the data. For example, the Standard Deviation (SD) of the SE scores is approximately 0.217. The 'Variance (Var)' column measures the dispersion, representing the variation around the mean value. For instance, the variance for LA scores is approximately 6,062. The notation 'Valid N = 741' indicates that there are no missing values in the dataset for the variables under study. This ensures a complete dataset for analysis and interpretation.

Table 6: Kendall's TauCorrelations Analysis

			CTS	CT	SE	SC	LE	LA
Kendall's tau_b	CTS	Correlation Coefficient	1.000	.064*	.002	-.021	-.029	-.012
		Sig. (2-tailed)	.	.013	.938	.418	.270	.644
		N	741	741	741	741	741	741
	CT	Correlation Coefficient	.064*	1.000	.069**	-.030	.094**	-.007
		Sig. (2-tailed)	.013	.	.008	.246	.000	.793
		N	741	741	741	741	741	741
	SE	Correlation Coefficient	.002	.069**	1.000	.130**	.038	.004
		Sig. (2-tailed)	.938	.008	.	.000	.140	.869
		N	741	741	741	741	741	741
	SC	Correlation Coefficient	-.021	-.030	.130**	1.000	.045	.015
		Sig. (2-tailed)	.418	.246	.000	.	.081	.561
		N	741	741	741	741	741	741
	LE	Correlation Coefficient	-.029	.094**	.038	.045	1.000	.102**
		Sig. (2-tailed)	.270	.000	.140	.081	.	.000
		N	741	741	741	741	741	741

	LA	Correlation Coefficient	-.012	-.007	.004	.015	.102**	1.000
		Sig. (2-tailed)	.644	.793	.869	.561	.000	.
		N	741	741	741	741	741	741
*. Correlation is significant at the 0.05 level (2-tailed).								
**. Correlation is significant at the 0.01 level (2-tailed).								

Table 6 displays the correlation matrix using Kendall's tau_b method, revealing the relationships among the variables CTS, CT, SE, SC, LE, and LA within a dataset comprising 741 data points for each variable. A correlation coefficient of 0.064 indicates a weak positive relationship between CTS and CT. This association is statistically significant at a 0.05 significance level, suggesting that it is not random. A correlation coefficient of 0.069 suggests a weak positive association between CT and SE. This association is also statistically significant at the 0.01 significance level, indicating a stronger and more meaningful relationship. The correlation coefficient between SE and SC is 0.130, indicating a moderate positive correlation. This correlation is highly significant at the 0.01 level, emphasizing a robust association between these two variables. CT and LE exhibit a correlation coefficient of 0.094, indicating a weak positive correlation. LE and LA demonstrate a correlation coefficient of 0.102, suggesting a weak positive association between these two variables. This correlation is highly significant at the 0.001 level, signifying a meaningful relationship. The correlation matrix provides valuable insights into the relationships among the variables, with varying degrees of strength and significance observed between them.

Table 7: ANCOVA Test Analysis

Dependent Variable: LA						
Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Intercept	Hypothesis	62626.149	1	62626.149	1864.896	.000
	Error	8722.740	259.748	33.582[a]		
CTS	Hypothesis	1055.100	25	42.204	1.049	.401
	Error	18382.045	456.795	40.241[b]		
SC	Hypothesis	662.874	25	26.515	.661	.894
	Error	18792.159	468.771	40.088[c]		
CTS * SC	Hypothesis	11511.958	264	43.606	1.310	.007

	Error	14185.412	426	33.299[d]		
a. .351 MS(SC) + .258 MS(CTS * SC) + .391 MS(Error)						
b. .674 MS(CTS * SC) + .326 MS(Error)						
c. .659 MS(CTS * SC) + .341 MS(Error)						
d. MS(Error)						

Table 7 presents the analysis of inter-subject effects for LA, focusing on the influence of various variables on academic performance. The intercept serves as the baseline and provides the mean score for academic performance when all independent variables are held constant. The hypothesis test for the intercept indicates a significant effect on academic performance (p < .001) for LA, with a T3 sum of squares (T3 = 62,626, t3 = 0.149).The hypothesis test for T3 (Creativity) reveals no significant effect on performance (p = .401). However, the interaction effect between CTS and SC, denoted as CTS * SC, demonstrates an impact on academic achievement (p = 0.007) with a type III sum of squares of 11,511.958. Therefore, it is imperative to further explore the interaction effect between CTS and SC to gain a more comprehensive understanding of their combined influence on academic achievement.

Table 8: Expected Mean Squares

Source	**Variance Component**			
	Var(SC)	**Var(CTS * SC)**	**Var(Error)**	**Quadratic Term**
Intercept	6.844	1.125	1.000	Intercept, CTS
CTS	.000	1.548	1.000	CTS
SC	19.503	1.513	1.000	
CTS * SC	.000	2.298	1.000	
Error	.000	.000	1.000	
a. For each source, the expected mean square equals the sum of the coefficients in the cells times the variance components, plus a quadratic term involving effects in the Quadratic Term cell.				
b. Expected Mean Squares are based on the Type III Sums of Squares.				

Table 8 presents the expected mean squares, calculated based on the type III sums of squares and the variance components attributed to each source. The expected mean square for the Intercept is determined by summing the coefficients in the cells (Intercept, CTS) and then multiplying this sum by the respective variance components (Var(SC), Var(CTS * SC), Var(Error)). The quadratic term involving effects in the Quadratic Term cell is also considered. For the Intercept, the expected mean square is found to be 6.844. In the case of the variable CTS, the expected mean square is calculated by multiplying the coefficients in the cells (CTS) by the corresponding variance components (Var(CTS * SC), Var(Error)). The quadratic term involving effects in the Quadratic Term cell is also included. The expected mean square for CTS is computed to be 1.548. These expected mean squares provide valuable insights into the variance components associated with the Intercept and the CTS variable, shedding light on their respective contributions to the overall analysis.

Table 9: Kappa Agreement Test Symmetric Measures

		Value	Asymptotic Standard Errora	Approximate Tb	Approximate Significance
Measure of Agreement	Kappa	-.009	.008	-1.053	.292
N of Valid Cases		741			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

Table 9 presents Kappa results, which is a symmetric measure of agreement used to assess the level of agreement among observers that exceeds what would be expected by chance. In this study, for example, Kappa is calculated as -0.009, with an asymptotic Standard Error (SSA) of 0.008. The approximate t-value for Kappa is 0.053, and the corresponding significance level is 0.292. A negative Kappa value indicates a slight disagreement among observers or raters regarding their assessments. However, since the absolute value of Kappa is relatively small and approaches zero, the level of agreement is considered insignificant or nearly insignificant. The analysis is based on a dataset comprising 741 valid cases, indicating that 741 cases or observations were included in the Kappa calculation. When interpreting the results, the p-value of 0.292 indicates that the observed agreement is not statistically significant.

Table 10: Regression Analysis

Model Summary[b]				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.132[a]	.017	.011	6.030
a. Predictors: (Constant), LE, CTS, SE, CT, SC				
b. Dependent Variable: LA				

Table 10 presents a model summary outlining key statistical measures of the regression model, which aims to predict the dependent variable LA using the predictor variables LE, CTS, SE, CT, and SC. The value of R is 0.132, indicating a weak positive relationship between the predictor variables and the dependent variable LA. The R square is 0.017, signifying that approximately

1.7% of the variability in the dependent variable LA can be explained by the predictor variables. These statistics provide insights into the predictive power of the model and the proportion of variance in the dependent variable that can be accounted for by the included predictor variables.

Table 11: Analysis of Variance for the Regression Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	475.818	5	95.164	2.618	.023[b]
	Residual	26721.745	735	36.356		
	Total	27197.563	740			
a. Dependent Variable: LA						
b. Predictors: (Constant), LE, CTS, SE, CT, SC						

Table 11 presents the results of the analysis of variance (ANOVA) for the regression model, which predicts the dependent variable LA using the predictors LE, CTS, SE, CT, and SC. The regression sum of squares (SQ) for this model is 495.818, indicating the total deviation of the dependent variable LA that can be explained by the predictors. ANOVA assesses the goodness of fit of the model to the data. The model comprises 5 predictors (LE, CTS, SE, CT) along with a constant term, resulting in 6 degrees of freedom (5 predictors + 1 constant term) for the regression. The mean square is calculated by dividing the sum of squares by their degrees of freedom. For the regression, the mean square is 95.164, and the F-ratio, which is a test statistic comparing the variability explained by the regression to the variability not explained by the residual, is calculated as 2.618. The associated significance level (p-value) for the F-test is 0.023. The statistically significant F-test suggests that the model has some predictive capability in explaining the variation in LA. However, further analysis and evaluation of individual predictor variables may be necessary to discern their specific contributions to the model's performance.

Table 12: Coefficients of Predictor Variables

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17.200	1.448		11.878	.000
	CTS	-.018	.037	-.018	-.496	.620
	CT	-.034	.038	-.034	-.904	.366
	SE	.016	.038	.016	.428	.669

	SC	-.003	.040	-.003	-.086	.931
	LE	.133	.038	.128	3.465	.001
a. Dependent Variable: LA						

Table 12 provides coefficient information regarding the relationship between the dependent variable CTS (CTS), along with its interactions with SE, SC, LE, and the dependent variable LA within a regression model. The model includes a constant term of 17.200, representing the estimated average value of the dependent variable LA when all predictor variables are set to zero. In this context, it signifies the estimated expected value of LA when all predictor variables are absent. The coefficient for CTS is -0.018. This indicates that for every unit increase in CTS, the dependent variable LA is estimated to decrease by 0.018 units. However, the coefficient is not statistically significant (p = 0.620), suggesting that there is no strong evidence to support the notion that CTS significantly impacts LA. The coefficient for CT is -0.034. This implies that for each unit increase in CT, the dependent variable LA is estimated to decrease by 0.034 units. Similar to CTS, the coefficient for CT is not statistically significant (p = 0.366). The coefficient for SE is 0.016, indicating that for every unit increase in SE, the dependent variable LA is estimated to increase by 0.016 units. The coefficient for LE is statistically significant (p = 0.001), suggesting that LE has a significant impact on LA. This coefficient implies that changes in LE are associated with changes in LA. Among the predictor variables considered, only LE demonstrates a statistically significant relationship with the dependent variable LA in this regression model.

Table 13: Residuals Statistics Analysis

	Minimum	**Maximum**	**Mean**	**Std. Deviation**	**N**
Predicted Value	17.16	20.96	19.02	.802	741
Residual	-18.132	35.685	.000	6.009	741
Std. Predicted Value	-2.327	2.416	.000	1.000	741
Std. Residual	-3.007	5.918	.000	.997	741
a. Dependent Variable: LA					

Table 13 presents residual statistics that describe the distribution and properties of residuals within a regression model for the dependent variable LA. The predicted values for LA fall within the range of 17.16 to 20.96, with an average of 19.02. These predicted values are estimated based on the regression model and the provided predictor variables. Residuals represent the differences between the observed values and the predicted values. The minimum residual value is -18.132, and the maximum residual value is 35.685. Standardized residuals range from -3.007 to -5.918. The mean residual is 0.000, and the standard deviation is 0.997. Standardizing the residuals allows for the measurement of the relative size of the residuals in comparison to their standard deviation.

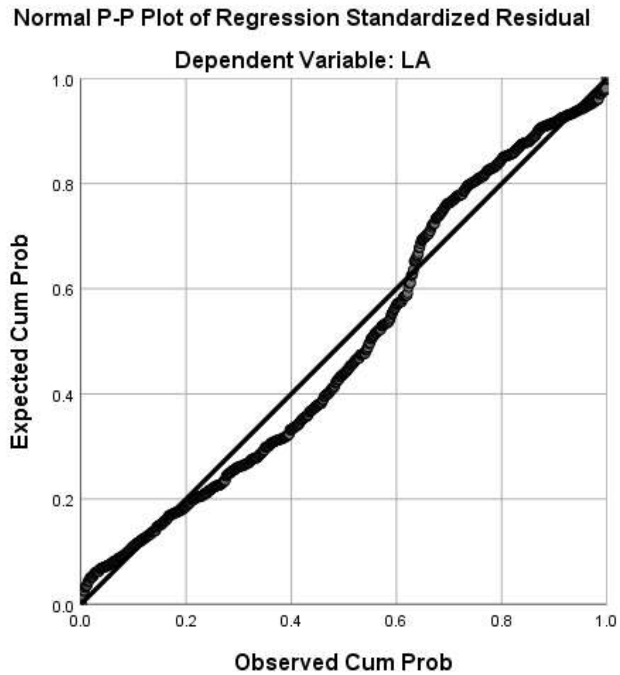

Figure 2: Normal P-P Plot of Regression Standardized Residual

Figure 2 displays the Normal P-P Plot of Regression Standardized Residuals. In this plot, the standard p-scores are graphed against the expected p-scores of the standardized residuals, assuming a normal distribution. The Normal P-P Plot is a crucial tool used by researchers to assess the validity of the normality assumption. This assumption holds significance in various statistical analyses, particularly in regression models. Deviations from normality in the residuals can impact the accuracy and reliability of regression results. The Normal P-P Plot of regression standardized residuals serves as a vital diagnostic tool for testing the normality hypothesis within regression analysis. Its primary purpose is to ascertain whether the statistical inferences drawn from the model remain valid and dependable in light of the normality assumption.

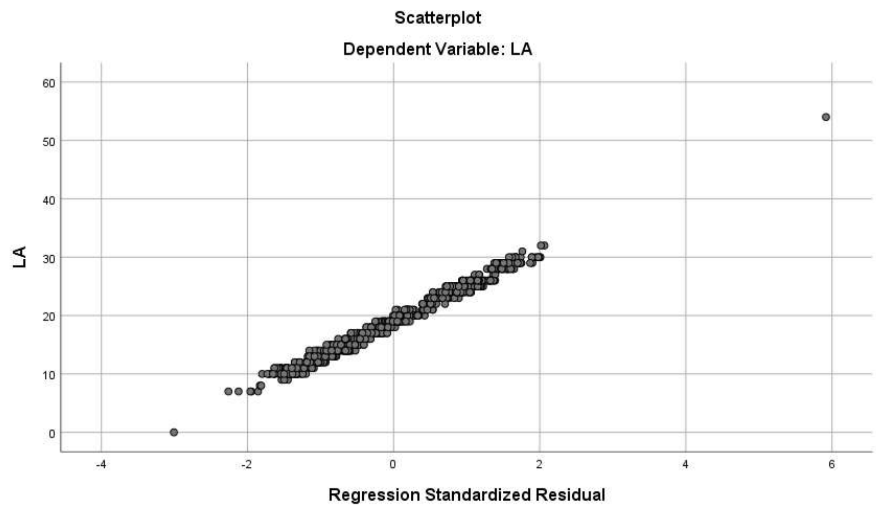

Figure 3: Scatter Plot of Regression Standardized Residuals

Figure 3 displays a scatter plot illustrating the regression standardized residuals for the dependent variable LA. A scatter plot serves as a visual representation of the relationship between predicted values and standardized residuals. In a well-fitting regression model, such as in the case of LA, the points on the scatter plot should be randomly distributed along the horizontal line (y = 0), which represents standardized residuals. This pattern signifies that the model's predictions are unbiased, and no systematic patterns are present in the residuals. This study utilizes the scatter plot of regression standardized residuals to diagnose the model's fit and test assumptions such as linearity, constant variance, and the independence of residuals.

Table 14: LSD Post Hoc Test Analysis

Dependent Variable: LA						
Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Intercept	Hypothesis	73024.385	1	73024.385	2211.916	.000
	Error	1542.783	46.731	33.014[a]		
CTS	Hypothesis	824.741	24	34.364	1.185	.372
	Error	447.633	15.441	28.991[b]		
CT	Hypothesis	999.559	25	39.982	1.949	.160
	Error	170.017	8.290	20.510[c]		

SC	Hypothesis	713.814	24	.	.	.
	Error	.	.[d]	.		
CTS * CT	Hypothesis	3902.403	120	32.520	.559	.884
	Error	307.103	5.282	58.139[e]		
CTS * SC	Hypothesis	4278.155	122	35.067	.603	.854
	Error	306.839	5.274	58.185[f]		
CT * SC	Hypothesis	3395.747	121	28.064	.485	.930
	Error	308.465	5.327	57.908[g]		
CTS * CT * SC	Hypothesis	298.599	5	59.720	2.003	.088
	Error	2176.500	73	29.815[h]		
a. .634 MS(SC) + .055 MS(CTS * SC) + .151 MS(CT * SC) + .108 MS(CTS * CT * SC) + .052 MS(Error)						
b. 1.193 MS(CTS * SC) - .237 MS(CTS * CT * SC) + .044 MS(Error)						
c. 1.208 MS(CT * SC) - .240 MS(CTS * CT * SC) + .033 MS(Error)						
d. Cannot compute the error degrees of freedom using Satterthwaite's method.						
e. .947 MS(CTS * CT * SC) + .053 MS(Error)						
f. .949 MS(CTS * CT * SC) + .051 MS(Error)						
g. .939 MS(CTS * CT * SC) + .061 MS(Error)						
h. MS(Error)						

Table 14 displays the results of a test of between-subjects effects and ANOVA for the dependent variable LA, considering various sources of variation. The hypothesis associated with the intercept has a significant effect on the dependent variable LA. The Type III Sum of Squares for the intercept is 73024.7895, with 1 degree of freedom. The Mean Square is 73024.7895 (2 degrees of freedom), and the F-value is 2211.916. The significance level (SIG) is reported as .000, indicating a highly significant effect. The CTS hypothesis does not have a significant effect on LA. The type III Sum of Squares for CTS is 824.741, with 24 degrees of freedom (df). The Mean Square is 34.364, and the F-value is 1.185. The significance level (SIG) is reported as .372, indicating no significant effect. The hypothesis related to CT does not have a significant effect on LA. The Type III Sum of Squares for CT is 999.559, with 25 degrees of freedom (df). The Mean Square is 39.982, and the F-value is 1.949. The significance level (SIG) is reported as .160, indicating no significant effect. The hypothesis related to the interaction between CT and SC does not have a significant effect on LA. The three-way interaction hypothesis between CTS, CT, and SC has a marginally significant effect on LA. The type III Sum of Squares for the three-way interaction is 298.599, with 5 degrees of freedom (df). The Mean Square is 59.720, and the F-value is 2.003. The significance level (SIG) is reported as .088, indicating marginal significance. The results of the ANOVA tests offer insights into the effects of various variables and their interactions on the dependent variable LA. While some variables, such as the intercept, exhibit significant effects on LA, others do not demonstrate a significant impact.

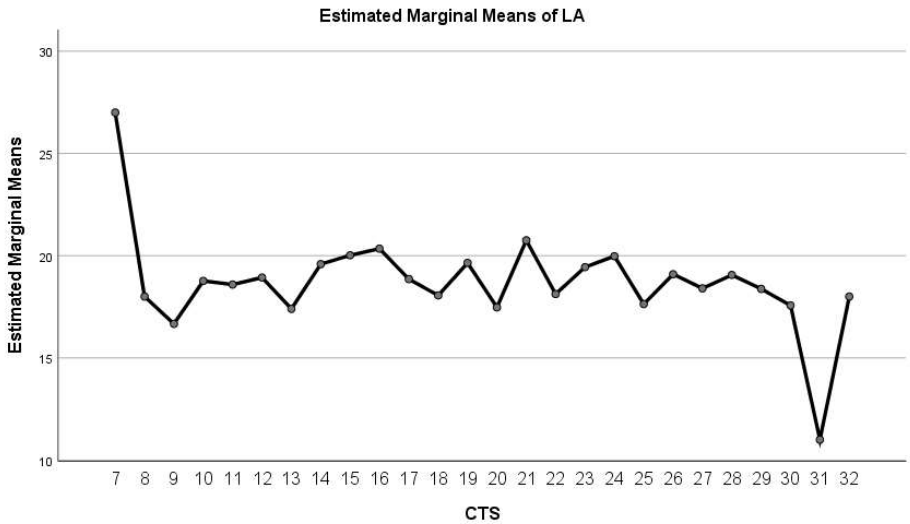

Figure 4: Estimated Marginal Means of LA

Figure 4 illustrates the estimated marginal means of LA, presenting the average or predicted values of the dependent variable LA at various levels of the predictor variables while keeping all other variables constant. Estimated marginal means are computed by averaging the predicted values for each level of the predictors, offering a more comprehensive understanding of the relationship between the dependent variable and the independent variables within the regression model. The figure depicting estimated marginal means offers a visual representation of the results obtained from the regression model, aiding researchers in grasping how the dependent variable LA fluctuates with varying combinations of predictor variable values.

6. RESEARCH CONCLUSION

Recent research in the realm of higher education has brought to light a critical aspect: the interplay between creativity and critical thinking within the context of chemistry. These findings have emphasized the profound influence of these cognitive abilities on students' performance in this subject. Through a thorough analysis, valuable insights have emerged, shedding light on the dynamic relationship between creativity, critical thinking, and academic achievement in the field of chemistry. The study reveals a positive and significant impact of creativity on students' performance in chemistry. Higher levels of creativity correlate with improved academic achievements in the subject, underscoring the importance of nurturing creative thinking skills among chemistry students to enhance their learning outcomes. Furthermore, the research demonstrates the pivotal role of critical thinking in students' success in higher education chemistry. Students with strong critical thinking abilities tend to excel in comprehending complex concepts, solving problems, and effectively applying their knowledge. Additionally, the study identifies a noteworthy interaction effect between creativity and critical thinking. These findings are supported by various statistical analyses, including reliability statistics, ANOVA with Cochran's Test, Intraclass Correlation Coefficient, descriptive statistics, Kendall's Tau correlations, regression analysis, and the LSD Post Hoc test. These analyses contribute to a better understanding of the interactions among different variables and their influence on student's academic performance in chemistry. The study suggests that, while some variables exhibit significant effects on academic performance, others do not have a substantial impact. This highlights the importance of considering the combined effect of creativity and critical thinking, which appears to be more influential on students' academic achievements than their contributions. Consequently, educators are encouraged to prioritize the simultaneous development of both creativity and critical thinking to foster comprehensive learning in the field of chemistry.

The findings provide significant implications for higher education institutions. They underscore the necessity of incorporating pedagogical approaches that promote creative and critical thinking within chemistry curricula. The implementation of instructional strategies that encourage active learning, problem-solving, and open-ended exploration can prove highly beneficial for students' academic development. This research emphasizes the importance of nurturing well-rounded students who possess both creative and critical thinking abilities. Such students are better equipped to confront real-world challenges and make meaningful contributions to scientific advancements and societal needs. While this study offers valuable insights, further research is encouraged to explore additional factors that may influence the relationship between creativity, critical thinking, and chemistry learning. Longitudinal studies and cross-disciplinary investigations can provide a more comprehensive understanding of these cognitive abilities and their impact across various academic disciplines. Consequently, the research reveals that creativity and critical thinking are essential factors influencing students' performance in chemistry at the higher education level. Cultivating and honing these cognitive skills can lead to improved learning outcomes and better-prepared graduates capable of addressing the complexities of the scientific field. The implementation of innovative teaching strategies and the fostering of a culture of creative inquiry can significantly contribute to the success of chemistry education at the higher education level.

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