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# ROLE OF PROBLEM-SOLVING ABILITY IN THE ACHIEVEMENT OF CHEMISTRY AT THE UNDERGRADUATE LEVEL

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**Abstract:** The acquisition of problem-solving skills is widely acknowledged as a crucial aspect of effective learning and academic success. In the context of undergraduate education, this holds particular significance in disciplines like chemistry, where the ability to tackle complex challenges is essential for comprehensive understanding and application of theoretical concepts. The objective of the study is to identify the factors that contribute to undergraduate student achievement in terms of problem-solving ability and chemistry Learning Experience (LE). By employing a multifaceted methodology, encompassing both quantitative and qualitative approaches, this study aims to explore the relationship between problem-solving ability and studentachievement in chemistry. The study utilizes the cross-sectional survey employed to investigate chemistry students' perceptions of problem-solving skills and their academic achievements.In addition, a series of carefully designed experiments and assessments will be administered to undergraduate chemistry students to evaluate their problem-solving capabilities in diverse scenarios.Through the analysis of collected data, this study aims to identify the relationship between problem-solving skills and academic success in the discipline. Moreover, the research will investigate the potential influence of various factors, such as teaching methodologies, students' prior exposure to problem-solving techniques, and individual learning styles, on their chemistry achievements. The study utilized a Problem-Solving Test consisting of four items to measure students' problem-solving skills and employed statistical analyses, including MANOVA, Spearman's ρ, and Pearson r correlation coefficients, as well as a quasi-meta-analysis to analyze the data, which is analyzed using SPSS software. The MANOVA results for the corrected model value of 1.201 with a significance of 0.30, the results revealed that students in the experimental group exhibited higher scores in learning motivation and problem-solving ability compared to the comparison group. These findings suggest that structured, semi-structured, and free problem-posing activities contribute to the enhancement of students' problem-solving skills and metacognitive awareness.
**Keywords:**Problem-Solving Ability**,** Quasi-Experimental Design, Pre-Test and Post-Test, MANOVA Test, Patton Analysis Technique, Metacognitive Awareness.

## 1. INTRODUCTION

In the realm of quantitative chemistry, students encounter various problem-solving tasks that involve several steps. A fundamental aspect crucial for addressing both individual and complex issues is the mastery of the critical thinking process [1]. Students equipped with this valuable skill can excel in all facets of their lives, effectively applying their abilities to navigate challenges and find solutions to encountered problems [2]. In this study, we explore the impact of students' critical thinking abilities on their achievement in the chemical reaction rate and the influence of temperature and concentration on reaction rate subjects; the participants come from several distinct departments [3]. Examining various factors influencing the education and learning of science, this study identifies determinants that affect first-year college students' success in science courses [4]. Utilizing distinct correlational analysis, college students (n= 253) were surveyed using a checklist instrument (CKI = 0.70) to determine the factors influencing their chemistry learning. This is the most challenging aspect of the introductory chemistry course for the majority of students taking it for the first time [5]. While few studies focus on critical thinking in science, the primary reason why undergraduates struggle to solve problems is their lack of understanding of the concepts on which the problems are based [6]. This study provides insights into the extent of undergraduate abilities to deal with contextual information in science problems by developing a reliable and valid measurement instrument [7].

The study could inform science educators to improve their teaching practices, prompt test developers to pay careful attention to context in problem design, and encourage further research to link context-based critical thinking skills to science concept mastery and application [8]. Studies comparing the approaches of novice students and experts have shown that experts can retrieve relevant concepts from their long-term memory more easily [9]. Science education often faces the challenge of students losing interest in learning science subjects, including chemistry [10]. Novices tend to immediately use formulas or attempt to apply algorithms when solving problems, while experts invest significant time in devising problem-solving strategies [11]. Despite practising analogies, many students struggle to apply them to chemistry problems [12]. Students typically require substantial practice when analogies are incorporated into the classroom. Research findings suggest that students tend to memorize and apply formulas for calculating chemical concentrations instead of fully understanding the units of solution concentration [13]. Additionally, students often fail to explain the symbols used in the formulas, leading to incorrect calculations [14]. Consequently, this study aims to assess the problem-solving skills of high school students in the context of solutions [15]. The study's primary objective is to investigate how the problem-posing approach influences students' problem-solving abilities and metacognitive awareness. The research also seeks to enhance and validate tests designed to measure problem-solving skills at different stages of knowledge development.

## 2. LITERATURE SURVEY

Nasution *et al* [16] suggested that this study aims to comprehend the connection between the academic success of female and male senior high school and university students and their capacity for critical and creative thinking. The findings indicate that, for both sexes, there was a positive correlation between students' critical thinking abilities, creative thinking abilities, and academic success in senior high school and university. In their study, Yu *et al* [17] aimed to investigate the impact of the flipped classroom on student performance and critical thinking abilities in science courses. The study also found that students' problem-solving abilities improve over time in flipped classrooms, which typically require a lengthy teaching period. In the meantime, the exploration discoveries uncovered that most students liked or unequivocally favoured the flipped study hall approach after they encountered it. Chi *et al* [19] proposed that the study assesses students' capacity to handle the contextual information embedded in science problems. The findings of this study could inform science educators to further develop their teaching practices, prompt test developers to pay careful attention to context, and encourage further research to relate context-based critical thinking abilities to science concept mastery and application. Nzomo *et al* [20] in this paper deliberate on how students' self-efficacy in chemistry is improved by inquiry-based learning in practical lessons. The results from correlation and regression analysis revealed areas of strength for a relationship between inquiry-based learning and students' self-efficacy in science ($r = 0.903$, $p < 0.05$, $R^2 = 0.8155$).

Abbhood *et al* [21] explored the impact of a curriculum based on the repulsive (allosteric) learning model, which emphasizes the development of chemistry and lateral thinking skills. The results revealed the superiority of the experimental group, which followed the curriculum based on the repulsive learning model, in terms of achievement and lateral thinking. Alt *et al* [22] acknowledged that while future problem-solving programs may have the potential to foster creativity and innovation skills in students, it remains challenging to quantify the benefits of such programs for higher education students. Findings indicated that participants' awareness of future issues, their confidence in generating innovative ideas, and their perceived creative behaviour increased at the end of the FPS program compared to its inception. Ekaputra *et al* [23] conducted a study to assess the effectiveness of the discovery learning model in practical exercises in further enhancing students' critical thinking abilities and creativity. The results of this study demonstrated that practicum learning using the discovery learning model effectively enhanced students' critical thinking and creativity, particularly among Science Education students. Ardianty *et al* [24] aimed to determine the effectiveness of IDEAL-type metacognitive instruction combined with STAD cooperative learning in improving students' self-efficacy and critical thinking skills in thermochemistry. Overall, students' self-efficacy and critical thinking skills improved, although the relationship between the two was weak. The assessment tools included problem-solving tests and a self-efficacy questionnaire. Rahmah *et al* [25] employed the MANOVA test and the Matched Example T-test in their research methodology. The study results demonstrated significant differences in the self-efficacy and critical thinking skills of students who engaged in problem-based learning compared to students who followed a conventional scientific approach to learning.

## 3. RESEARCH PROBLEM DEFINITION AND MOTIVATION

Chemistry is a challenging and demanding subject that requires critical and analytical thinking skills. Problem-solving skills may be the key factors that determine a student's success in chemistry. However, little research has been done specifically on the role of problem-solving abilities affecting students' performance in undergraduate chemistry courses. Identifying the relationship between problem-solving abilities and academic performance in chemistry could help us understand the factors that influence students' success in this field. By examining this interlinkage, the study aims to elucidate the significance of problem-solving training and effective teaching approaches to improve students' problem-solving abilities and academics in Chemistry at the undergraduate level. Additionally, the purpose of this study is to investigate how different modalities of problem-solving, including approach strategies, cognitive reasoning, and metacognitive abilities, may affect student performance in Chemistry. Furthermore, the study will also explore whether problem-solving ability acts as an enabler or inhibitor in the connection between other factors such as prior experience, learning styles, study patterns, and academic activities in Chemistry. The results of this study could have important implications for curriculum development, teaching methods, and student support programs, helping educators create a supportive learning environment that fosters students' problem-solving abilities and promotes academic achievement in undergraduate Chemistry courses.

The motivation to study the impact of problem-solving on undergraduate Chemistry success stems from the significance of problem-solving in the field of science and its potential influence on students' academic performance. Chemistry, being one of the most intricate subjects in science, requires students to grasp theoretical concepts and apply them to solve practical problems. Proficiency in problem-solving is crucial for chemistry students as it enables them to analyse and elucidate experimental findings, devise appropriate methodologies, and draw meaningful conclusions. A deeper understanding of how problem-solving skills correlate with academic performance in chemistry can provide educators with valuable insights into the factors that contribute to student's success in this challenging discipline. Furthermore, in the rapidly evolving world, problem-solving skills have become more critical than ever for students' future careers and achievements. Graduates equipped with strong problem-solving abilities are in high demand across various industries, including scientific research and development. Therefore, establishing a connection between problem-solving skills and academic performance in chemistry can have broader implications for students' future professional journeys. By recognizing the relationship between problem-solving proficiency and success in chemistry, educational institutions and instructors can develop tailored interventions and teaching methodologies to enhance students' problem-solving skills. This will empower them to excel in chemistry and prepare them for a competitive and ever-changing job market. Through this investigation, the objective is to furnish students and educators with valuable insights that will facilitate a better comprehension of the elements contributing to academic accomplishments in Chemistry and beyond.

## 4. RESEARCH PROPOSED METHODOLOGY

The purpose of this study is to identify the factors that contribute to undergraduate student achievement in terms of problem-solving abilities and the Chemistry Learning Experience (LE). By exploring diverse pedagogical approaches, evaluating the efficacy of problem-based learning, and assessing students' problem-solving strategies, this research aims to shed light on the pivotal factors influencing chemistry achievement. Through a comprehensive analysis of these elements, this study seeks to pave the way for enhanced teaching methodologies and enriched learning experiences in the undergraduate chemistry domain, ultimately empowering students to overcome academic hurdles and achieve excellence in this critical field of study.

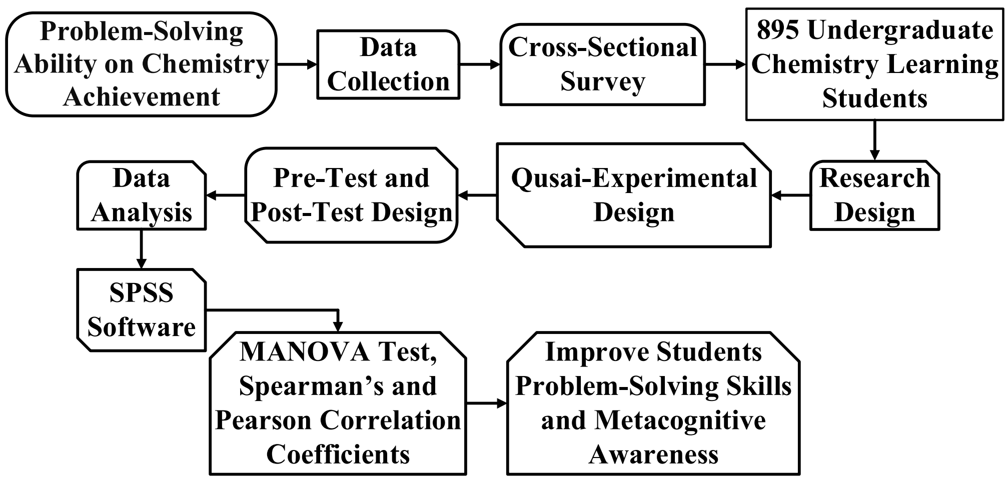


**Figure 1:** Block Diagram of the Proposed Work

Figure 1 illustrates the relationship between problem-solving proficiency and the chemistry learning experience (LE) that equips undergraduate students for academic achievement. This figure elucidates the design methodology employed in the study. Quantitative data was collected, and the number of participants involved in the data collection process was outlined. The study utilized specific equipment for data collection, focusing on the impact of the problem-posing approach on students' problem-solving abilities and metacognition in the field of chemistry education. This article delves into the development and validation of tests designed to assess success across three levels of the knowledge structure, thereby evaluating students' problem-solving capabilities comprehensively. The research adopted a quasi-experimental design, incorporating both a pre-test group and a control group. The pre-test group was subjected to assessments before the experimental intervention, while the control group did not receive the intervention. Subsequently, the performance of students in the experimental group and the control group was compared, highlighting the effectiveness of the problem-posing approach in enhancing problem-solving skills in chemistry education.

### 4.1Research Design

The focus of this study was to determine whether the problem-posing technique, commonly used for solving math problems in chemistry education, could also be effectively applied to solving chemistry problems in science education. An experiment was conducted to assess the impact of using the problem-posing approach on students' ability to solve chemistry problems and their metacognitive skills in science education. During the data collection phase, a quasi-experimental model was employed, which included pre-tests, post-tests, and control groups. The Problem-solving Inventory and Metacognition Awareness Scale were administered as pre-tests and post-tests for both the experimental and control groups.

## 4.2 Data Collection

A quantitative study employing a descriptive research design was undertaken to investigate the relationship between problem-solving skills and academic performance among undergraduate chemistry students. Data collection encompassed the utilization of a test created by the researcher, comprising algorithm-based questions, conceptual problems, and open-ended inquiries. To ascertain the test's validity, content validation was carried out with input from experts, including chemistry educators. The demographic characteristics of the study participants are presented in table 1. The performance scores on this test were then compared to the student's academic records in Chemistry courses. The results of this study contribute to our understanding of the importance of problem-solving skills in academic achievement, particularly in challenging subjects like Chemistry. Additionally, the findings may inform educators and institutions about the potential benefits of incorporating problem-solving-focused teaching methods into Chemistry curricula to enhance students' overall performance and comprehension of the subject.

**Table 1:**Demographic Characteristics

| Characteristics | Frequency | Percentage |
|---|---|---|
| **Gender** | | |
| Male | 448 | 50.0 |
| Female | 447 | 49.9 |

The study included 895 undergraduate students, comprising 448 males and 447 females, who were enrolled in the chemistry major program. Data collection took place during the 13th week of the chemistry class for that semester. The questionnaire consisted of two sections: section A contained calculation questions, while section B included multiple-choice questions and a complex problem-solving question that required higher-order thinking to address real chemistry problems. Data analysis was performed using Statistical Package for Social Sciences version 15.0 for Windows (SPSS) and involved descriptive statistics such as frequency and percentage. A passing score, indicating a higher level of subject comprehension, was defined as 40% or higher, while a score below 40% denoted a lower level of comprehension. The study aimed to compare problem-solving skills with chemistry proficiency at the undergraduate level, seeking to uncover the significance of problem-solving skills (PSS) in influencing academic performance in the field of chemistry at the undergraduate level.

### *4.2.1Data Collection Tools*

The authors developed a test comprising 5 open-ended questions, which served as both pre- and post-tests in the study. The content validity of the test underwent evaluation by 2 experienced chemistry teachers and 2 academicians with expertise in chemistry education. The test aimed to gauge students' familiarity with fundamental organic chemistry concepts before the treatment and to measure any changes in their thinking following the treatment. Each item on the test had a maximum score of 10 points, and the total maximum score for the entire test was set at 50 points.

**4.3 Test Effects**

Evaluations typically involve the administration of tests, both before and after the intervention. It is important to acknowledge that some of the observed improvements in test scores may be attributed to the testing process itself. For instance, participants may better recall questions from the pre-test, or the questions themselves may serve as a form of learning stimulus, raising awareness and facilitating learning irrespective of the actual intervention. To mitigate the potential influence of the test-taking experience, it is advisable to employ two or more 'equivalent' versions of the test. These versions should be carefully balanced and distributed among participants, both at the pre-test and post-test stages. This approach helps ensure that any observed changes in test scores are more likely to be attributed to the intervention itself rather than the testing process. However, to gain a comprehensive understanding of whether learning occurred solely as a result of taking the test, it is essential to include a group of participants who did not engage in the test. This results in four distinct participant groups:

- No-intervention pre-test and post-test group: Participants who neither received the intervention nor took the pre-test and post-test.
- Pre-test with intervention and post-test without intervention group: Participants who completed the pre-test with the intervention but did not take the post-test.
- Post-test without intervention only group: Participants who did not engage in the intervention but took the post-test.
- Post-test with an intervention-only group: Participants who received the intervention and completed the post-test.

This comprehensive approach allows researchers to disentangle the effects of the intervention, the testing process, and any potential learning that occurs independently of the intervention, providing a more nuanced evaluation of the intervention's impact.

***4.3.1Quasi-Experimental Design***

A quasi-experimental design can be employed to investigate the relationship between problem-solving ability and academic achievement in the field of chemistry. This study aims to explore whether enhancing problem-solving skills among chemistry students leads to improved performance in the subject. To conduct this research, a random sample of students can be selected from a specific school or educational institution. These students can then be divided into two groups: the experimental group and the control group. The experimental group will receive targeted interventions and training sessions designed to enhance their problem-solving skills, while the control group will not receive any additional interventions and will follow the standard chemistry curriculum provided by the educational institution. The interventions provided to the experimental group may include problem-solving workshops, collaborative learning activities, and the utilization of technology-based tools specifically designed to enhance problem-solving skills in the context of chemistry. In contrast, the control group will receive traditional instruction following the standard curriculum. To assess the impact of the intervention on chemistry performance, standardized chemistry tests will be administered to both groups at the beginning and conclusion of the study. This will allow for a comparative analysis of the academic achievements of the two groups and provide insights into the effectiveness of the problem-solving interventions.

In this study, the scores of each group will be compared to determine whether the experimental group, which received the intervention, exhibited a greater improvement in their chemistry achievement compared to the control group. The primary objective of this research is to assess the impact of problem-solving interventions on chemistry achievement using a semi-experimental research design. The findings of this study hold the potential to shed light on the effectiveness of specific approaches aimed at enhancing problem-solving skills in chemistry education. Ultimately, these insights can contribute to the refinement of instructional methods and lead to improved student performance in the field of chemistry. To evaluate the participants' performance, an achievement test in chemistry was administered both as a pre-test and post-test. Additionally, the study utilized several assessment tools, including the Context-Based Chemistry Motivation Scale (CBCMS), the Attitude Towards the Chemistry Lessons Scale (ATCLS), and unit achievement tests. These instruments were administered before the experimental intervention commenced. Following the experimental phase, both the experimental and control groups underwent further assessment, which included the CBCMS test, ATCLS test, and unit achievement tests as post-tests.

#### *4.3.2Pre-Test and Post-Test Design*

The pre-test and post-test designs were utilized to assess and compare the performance of students in both the experimental group and the control group before and after the intervention. Initially, all students, regardless of group assignment, completed a pre-test to establish their baseline chemistry performance levels. This initial assessment aimed to provide a reference point for evaluating any variations in performance between the intervention and control groups. Following the pre-test, both groups underwent the intervention.Subsequently, a post-intervention assessment was administered to all participants, allowing for a comparison of their performance after the intervention with their baseline performance. By analysing the results of both the pre-test and post-test, researchers could ascertain whether the intervention had a significant impact on the academic performance of students in either group and whether any noteworthy changes occurred as a result. This research design facilitated the evaluation of the intervention's effectiveness and enabled a direct comparison between the experimental and control groups in terms of their improvements in chemistry performance.Furthermore, the pre-test and post-test design is a valuable approach for measuring the influence of problem-solving ability on chemistry achievement. In this study, a group of chemistry students from a specific educational institution was selected.These students initially completed a pre-test designed to assess their problem-solving abilities and proficiency in chemistry.

The pre-test consisted of exercises and questions designed to evaluate participants' problem-solving skills in a chemistry context, encompassing tasks such as analyzing chemical equations, solving chemistry-related problems, and designing experiments.Following the pre-test, participants received targeted interventions or training aimed at enhancing their problem-solving skills in the field of chemistry. These interventions could include classroom-based exercises that emphasize critical thinking and problem-solving techniques, as well as hands-on laboratory exercises. The duration and intensity of the interventions may vary based on the specific research design.After the intervention period, a follow-up test, referred to as the post-test, was administered to assess participants' problem-solving abilities and their performance in chemistry once again. By comparing the results of the pre-test and post-test, researchers could determine whether the intervention had a substantial impact on participants' problem-solving skills and overall performance in the realm of chemistry. The adoption of the pre-test and post-test design allows for a comprehensive evaluation of the effectiveness of interventions in enhancing problem-solving skills and their subsequent influence on academic achievement in chemistry. This research approach provides valuable insights for educators and researchers seeking to identify effective methods for improving problem-solving abilities in chemistry education and evaluating the impact of intervention or training programs.

## 5. EXPERIMENTATION AND RESULT DISCUSSION

The most pivotal and compelling areas of research pertain to problem-solving's role in undergraduate chemistry education. Problem-solving stands as a foundational skill in chemistry, necessitating the application of theoretical knowledge to real-world scenarios and the generation of innovative solutions to intricate chemical challenges. Investigating the influence of problem-solving skills (PSS) on students' academic performance in chemistry presents an opportunity to glean valuable insights into effective pedagogical methods and curriculum enhancements for fostering improved learning outcomes. This research endeavours to explore the nexus between problem-solving skills and academic achievement within the realm of undergraduate chemistry education. It seeks to elucidate the significance of problem-solving skills in the academic attainment of students in this fundamental scientific discipline. By elucidating the interrelationships among variables such as learning experiences (LE), problem-solving skills (PSS), metacognitive awareness (MA), and student achievements (SA), this study aspires to contribute to the advancement of chemistry education and the cultivation of proficient chemists poised to drive future advancements in the field of science.

**Table 2:** Simulation System Configuration

| | |
|---|---|
| SPSS Statistical Tool | Version 23.0 |
| Operation System | Windows 10 Home |

| | |
|---|---|
| Memory Capacity | 6GB DDR3 |
| Processor | Intel Core i5 @ 3.5GHz |

Table 2 depicts the simulation configuration table. The data were subsequently analysed to test the null hypothesis, it analysed the problem-solving skills of undergraduate students. This result investigates the achievement of chemistry in undergraduate students, and the analysis is performed based on descriptive statistics, Multivariate Tests, t-tests, and normality tests.

**Table 3:**Descriptive Statistics Analysis

| | **N** | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** | **Skewness** | | **Kurtosis** | |
|---|---|---|---|---|---|---|---|---|---|
| | **Statistic** | **Statistic** | **Statistic** | **Statistic** | **Statistic** | **Statistic** | **Std. Error** | **Statistic** | **Std. Error** |
| **LE** | 895 | 0 | 48 | 19.03 | 5.994 | .264 | .082 | -.606 | .163 |
| **PSS** | 895 | 8 | 32 | 19.20 | 5.789 | .166 | .082 | -1.176 | .163 |
| **MA** | 895 | 8 | 54 | 19.21 | 6.135 | .571 | .082 | .923 | .163 |
| **SA** | 895 | 8 | 46 | 19.03 | 5.897 | .261 | .082 | -.809 | .163 |
| **Valid N (listwise)** | 895 | | | | | | | | |

Table 3 presents descriptive statistics for four variables: LE (Chemistry Learning Experience), PSS (Problem-Solving Skills), MA (Metacognition Awareness), and SA (Study Anxiety) based on a dataset containing 895 observations. These statistics offer valuable insights into the characteristics of the data, allowing for a better understanding of each variable's central tendency, variation, and distribution. For the variable "LE," the data ranges from a minimum of 0 to a maximum of 48. The mean value is 19.03, and the standard deviation (SD) is 5.994. The skewness is approximately 0.264, indicating a slightly positively skewed distribution. Additionally, the kurtosis has a value of about 0.606, suggesting a platykurtic distribution with tails that are slightly lighter than those of a normal distribution. Moving to the "PSS" variable, its minimum value is 8, while the maximum is 32. The mean for this variable is 19.20, and the standard deviation (SD) is 5.789. The skewness is approximately 0.166, indicating a slight positive skew. The kurtosis value is around -1.176, indicating a platykurtic distribution with tails lighter than those of a normal distribution. Regarding the "MA" variable, the minimum value is 8, and the maximum is 54. The mean value for MA is approximately 19.21, with a standard deviation (SD) of 6.135. The skewness is approximately 0.571, suggesting a moderately positively skewed distribution. The kurtosis is around 0.923, indicating a distribution that is close to normal. Finally, for the "SA" variable, the minimum value is 8, and the maximum is 46. The mean value is about 19.03, and the standard deviation (SD) is 5.897. The skewness is approximately 0.261, indicating a slightly positively skewed distribution. The kurtosis is approximately -0.809, suggesting a platykurtic distribution with tails lighter than those of a normal distribution. These descriptive statistics provide a comprehensive overview of the dataset, helping to identify patterns and characteristics within each variable.

**Table 4:**One-Sample Statistics Analysis

| | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| LE | 895 | 19.03 | 5.994 | .200 |
| PSS | 895 | 19.20 | 5.789 | .194 |
| MA | 895 | 19.21 | 6.135 | .205 |
| SA | 895 | 19.03 | 5.897 | .197 |

Table 4 presents one-sample statistics for the variables 'LE,' 'PSS,' 'MA,' and 'SA.' The variable 'LE' exhibits a mean score of 19.03, a standard deviation (SD) of 5.994, and a standard error of the mean (SEM) of 0.200. These statistics suggest that the mean value of 'LE' in the population is likely to be close to 19.03, and the SEM represents the margin of error in estimating this population mean. Similarly, the variable 'PSS' has a mean value of approximately 19.20, with a standard deviation (SD) of 5.789 and a standard error of the mean (SEM) of 0.194, indicating a comparable level of precision in estimating the population mean. The variable MA possesses a mean value of approximately 19.21, slightly higher than the mean values of the previous two variables. The standard deviation (SD) for 'MA' is 6.135, with a standard error of the mean (SEM) of 0.205. Finally, the variable 'SA' has a mean value of 19.03, and its standard deviation (SD) is 5.891, with a standard error of the mean (SEM) of 0.197. These one-sample statistics offer a comprehensive overview of the central tendency and variability within each variable in the sample. They serve as valuable insights into the characteristics of the data and can be leveraged to make inferences about the corresponding population parameters.

**Table 5:**One-Sample T-Test Analysis

| | Test Value = 45 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| LE | -129.650 | 894 | .000 | -25.974 | -26.37 | -25.58 |
| PSS | -133.311 | 894 | .000 | -25.797 | -26.18 | -25.42 |

| | | | | | | |
|---|---|---|---|---|---|---|
| MA | -125.768 | 894 | .000 | -25.791 | -26.19 | -25.39 |
| SA | -131.736 | 894 | .000 | -25.966 | -26.35 | -25.58 |

Table 5 presents the results of one-sample analyses for four variables: LE (Chemistry Learning Experience), PSS (Problem-Solving Skills), MA (Metacognition Awareness), and SA (Study Anxiety), based on a dataset containing 895 observations. The test value used for this analysis is 45. The primary objective of these one-sample analyses is to determine whether the mean for each variable significantly differs from the test value of 45. For the variable "LE," the mean difference is -25.974, and the 95% confidence interval (CI) for the difference in means ranges from -26.37 to -25.58. The p-value is close to 0.000, leading to the rejection of the null hypothesis that the mean of variable "LE" equals the test value of 45. The highly negative t-statistic indicates that the mean of "LE" is significantly less than 45. Similarly, for the variable "PSS," the mean difference ranges from -25.797 to -26.18 to -25.42, and the p-value is close to 0.000, leading to the rejection of the null hypothesis. The highly negative t-statistics suggest that the mean of "PSS" is significantly less than 45. For the variable "MA", the mean difference is -25.791, with a 95% confidence interval (CI) of -26.19 to -25.39. The null hypothesis is rejected for "MA" due to the very small p-value (close to 0.000), and the highly negative t-statistic indicates that the mean of "MA" is significantly less than 45. Lastly, for the variable "SA," the mean difference is -25.966, and the 95% confidence interval (CI) ranges from -26.35 to -25.58. The extremely small p-value (nearly 0.000) provides strong evidence against the null hypothesis, and the highly negative t-statistics reveal a significant relationship with the variable under examination. In summary, the results of these one-sample tests indicate that all four variables (LE, PSS, MA, and SA) have significantly lower mean values than the test value of 45. The highly negative t-statistics and small p-values further support the rejection of the null hypothesis for each variable.

**Table 6:**SpearmanCorrelations Analysis

| | | | **LE** | **PSS** | **MA** | **SA** |
|---|---|---|---|---|---|---|
| Spearman's rho | LE | Correlation Coefficient | 1.000 | .227** | .035 | -.005 |
| | | Sig. (2-tailed) | . | .000 | .291 | .873 |
| | | N | 895 | 895 | 895 | 895 |
| | PSS | Correlation Coefficient | .227** | 1.000 | .161** | .008 |
| | | Sig. (2-tailed) | .000 | . | .000 | .805 |
| | | N | 895 | 895 | 895 | 895 |
| | MA | Correlation Coefficient | .035 | .161** | 1.000 | .168** |
| | | Sig. (2-tailed) | .291 | .000 | . | .000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | N | 895 | 895 | 895 | 895 |
| | SA | Correlation Coefficient | -.005 | .008 | .168** | 1.000 |
| | | Sig. (2-tailed) | .873 | .805 | .000 | . |
| | | N | 895 | 895 | 895 | 895 |
| **. Correlation is important at the 0.01 level of (2-tailed). | | | | | | |

Table 6 displays the correlation coefficients, specifically Spearman's rho, for the four variables ('LE,' 'PSS,' 'MA,' and 'SA') based on a dataset comprising 895 observations. These correlation coefficients offer insights into the strength and direction of relationships between pairs of variables. First, the correlation between 'LE' and 'PSS' is statistically significant at $p < 0.01$, indicating a slightly positive relationship between these two variables. A positive correlation coefficient implies that higher values of 'LE' correspond to higher values of 'PSS.' However, 'LE' does not exhibit a significant linear correlation with 'MA,' with $p > 0.05$. Similarly, there is no significant linear correlation between 'LE' and 'SA'. The relationship between 'PSS' and 'MA,' is statistically significant ($p = 0.01$), suggesting that higher values of 'PSS' are associated with higher values of 'MA.' However, there is no statistically significant linear correlation between 'PSS' and 'SA,' with $p > 0.05$. The relationship between 'MA' and 'SA' is statistically significant ($p < 0.05$ at the 0.01 level), indicating a slightly positive relationship between these two variables. In general, higher values of 'MA' are correlated with higher values of 'SA'. The Spearman's rho correlation coefficients reveal strong positive correlations between 'LE' and 'PSS,' 'PSS' and 'MA,' and 'MA' and 'SA.' 'LE' shows a weak negative correlation with 'SA,' while no statistically significant correlations exist between 'LE' and 'MA', 'LE' and 'SA,' or 'PSS' and 'SA'.

**Table 7:** Normality Test Analysis

| | **SA** | **Kolmogorov-Smirnov**[a] | | | **Shapiro-Wilk** | | |
|---|---|---|---|---|---|---|---|
| | | **Statistic** | **df** | **Sig.** | **Statistic** | **df** | **Sig.** |
| | 18 | .172 | 30 | .024 | .909 | 30 | .014 |
| | 19 | .161 | 57 | .001 | .927 | 57 | .002 |
| | 20 | .139 | 26 | .200* | .927 | 26 | .067 |
| | 21 | .228 | 19 | .011 | .852 | 19 | .007 |
| | 22 | .178 | 9 | .200* | .939 | 9 | .569 |
| | 23 | .137 | 49 | .022 | .927 | 49 | .005 |
| | 24 | .135 | 67 | .004 | .924 | 67 | .001 |
| | 25 | .125 | 42 | .095 | .904 | 42 | .002 |
| | 26 | .150 | 70 | .000 | .916 | 70 | .000 |
| | 27 | .210 | 9 | .200* | .946 | 9 | .651 |
| | 28 | .155 | 51 | .004 | .938 | 51 | .011 |
| | 29 | .147 | 23 | .200* | .918 | 23 | .061 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30 | .215 | 12 | .130 | .870 | 12 | .066 |
| | 31 | .260 | 2 | . | | | |
| PSS | | | | | | | |
| | 18 | .193 | 30 | .006 | .883 | 30 | .003 |
| | 19 | .130 | 57 | .017 | .935 | 57 | .005 |
| | 20 | .149 | 26 | .145 | .916 | 26 | .036 |
| | 21 | .161 | 19 | .200* | .914 | 19 | .086 |
| | 22 | .193 | 9 | .200* | .890 | 9 | .202 |
| | 23 | .189 | 49 | .000 | .912 | 49 | .001 |
| | 24 | .138 | 67 | .003 | .936 | 67 | .002 |
| | 25 | .213 | 42 | .000 | .908 | 42 | .003 |
| | 26 | .160 | 70 | .000 | .926 | 70 | .001 |
| | 27 | .123 | 9 | .200* | .973 | 9 | .919 |
| | 28 | .106 | 51 | .200* | .958 | 51 | .066 |
| | 29 | .187 | 23 | .036 | .920 | 23 | .066 |
| | 30 | .167 | 12 | .200* | .883 | 12 | .096 |
| | 31 | .260 | 2 | . | | | |
| *. This is a lower bound of the true significance. | | | | | | | |
| a. Lilliefors Significance Correction | | | | | | | |
| c. LE is constant when SA = 46. It has been omitted. | | | | | | | |
| d. PSS is constant when SA = 46. It has been omitted. | | | | | | | |

Table 7 presents standard deviation test results for two variables (SA and PSS) using the Kolmogorov-Smirnov (KSM) and Shapiro-Wilk tests. It is a lower limit of true significance" suggests that the reported level of significance may be conservative, possibly leading to a lower likelihood of rejecting the null hypothesis when it is indeed true.Additionally,the Lilliefors significance correction indicates that the significance correction method known as "Lilliefors correction" may have been employed in the tests. Furthermore, it is mentioned that "LE" remains constant when "SA" equals 46, resulting in the omission of data points with these values from the normality tests of 'SA' and 'PSS'. Conversely, 'PSS' remains constant when 'SA' equals 46, and these data points are also omitted.The normality test results for each level of "SA" help determine whether the data for "LE" and "PSS" at different levels of "SA" follow a normal distribution. This is crucial for making predictions about the data's distribution in statistical analysis and modelling.

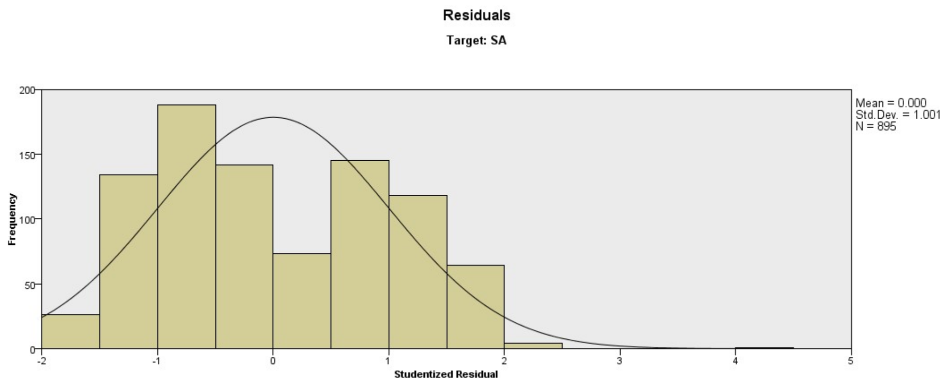


**Figure 2:** Standardized Residual Histogram Plot of Dependent Variable SA

Figure 2 illustrates a standard deviation histogram plot depicting standardized residuals. This context focuses on a dependent variable labelled as "SA," which shows its standardized residuals. The histogram plot visually represents the distribution of standard deviations within the model predicting the "SA" variable. Notably, the standard deviation histogram exhibits bell-shaped curves centred around zero. This bell curve pattern serves as a visual indicator of the model's standard deviations being evenly distributed around the mean. Such distribution underscores the notion that the model is a good fit for the provided data.

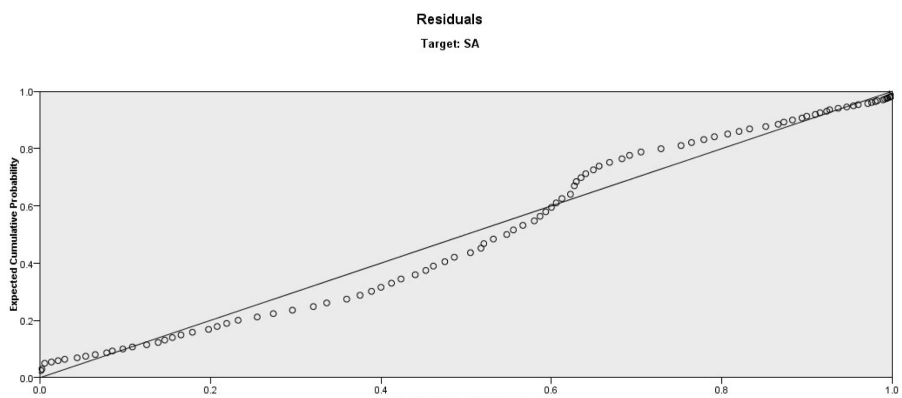


**Figure 3:** Observed Cumulative Probability Plot of Dependent Variable SA

The P-P residuals plot for SA supports the normal distribution of residuals, as shown in figure 3. There is no multicollinearity between independent variables (i.e., all VIFs and variance inflation factors are < 1.15) within the recommended limit of 3. The observed cumulative probability is 1.0.

**Table 8:** Stem andLeaf Plot of Variable LE

| **LE Stem-and-Leaf Plot for** |
| --- |

| SA= 10 | |
|---|---|
| **Frequency** | **Stem & Leaf** |
| 10.00 | 1 .1123444444 |
| 15.00 | 1 .566666678888899 |
| 10.00 | 2 .0000011224 |
| 6.00 | 2 .566699 |
| 1.00 | 3.0 |
| Stem width: 10 | |
| Each leaf:1 case(s) | |

Table 8 presents a stem-and-leaf plot, revealing the distribution of the variable "LE" for instances where "SA" equals 10. Specifically, the table provides a breakdown of the frequencies within the following cases. There are 10 instances with an "LE" value of 11 when "SA" is equal to 10. In cases where "SA" equals 10, there are 15 instances with "LE" values ranging from 12 to 14. Similarly, 10 instances fall within the "LE" value range of 20 to 24 for "SA" equal to 10. Additionally, there are 6 cases where "LE" values range from 25 to 29 for "SA" equal to 10. Lastly, there is a single case with an "LE" value of 30 when "SA" equals 10. The stem width in this representation is set at 10, with each leaf representing a single case. This stem-and-leaf plot effectively summarizes the frequency and distribution of "LE" within instances where "SA" is equal to 10.

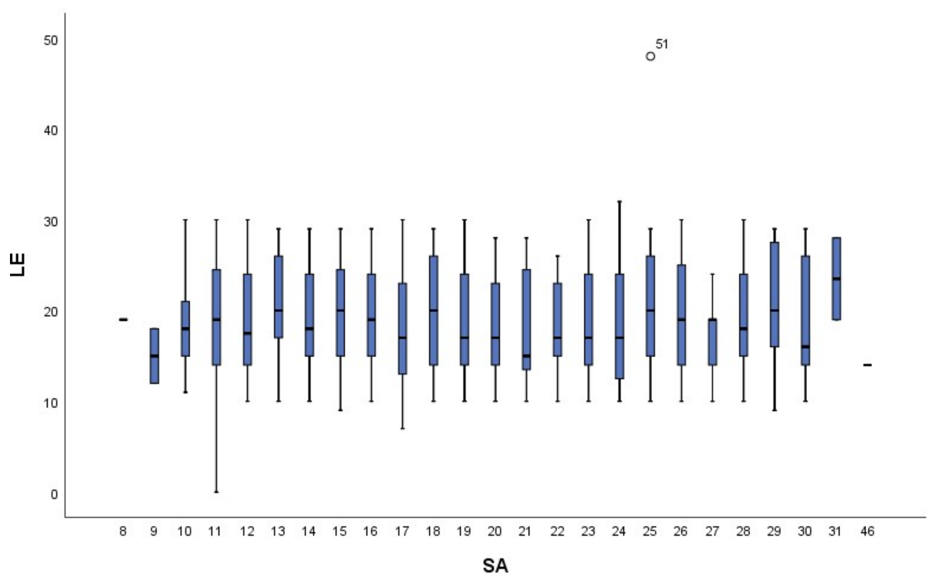


**Figure 4:**Box Plot Analysis of Variables SA and LA

Figure 4 displays the Box-and-Whisker Plot, an analysis of SA and LE (Survival Analysis and Life Expectancy). This visualization represents key statistical measures, including the median, quartiles, and outliers. The central box in the plot represents the Interquartile Range (IQR), which accounts for the middle 50% of the data. The upper and lower edges of the box signify the 25th and 75th percentiles (Q1 and Q3, respectively). In the box, the line represents the median. When the data is sorted in ascending order, the median corresponds to the middle value. The Box-and-Whisker Plot for "LE" follows the same structure as that for "SA", including IQR, Median, Whiskers, and Outliers specific to "LE". Conducting a box plot analysis enables a quick comparison of the central trends and distributions between "SAs" and "LEs," facilitating the identification of significant differences or similarities.

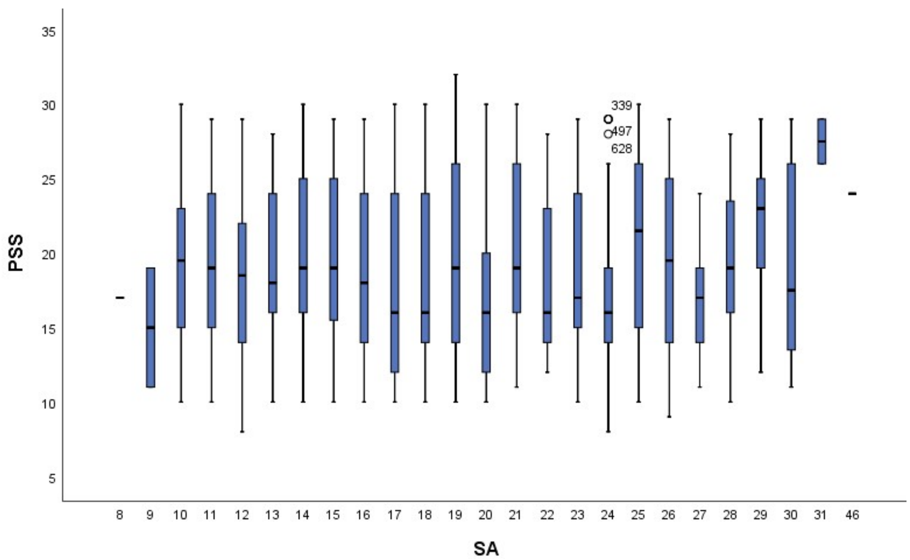


**Figure 5:** Plot Analysis of Variables SA and PSS

Figure 5 depicts a plot analysis involving the variables SA and PSS. Within this plot, the central element is a box that signifies the interquartile range (IQR), encompassing the central 50% of the data distribution. The upper and lower boundaries of this box correspond to the 25th percentile (Q1) and the 75th percentile (Q3), respectively. Additionally, a line within the box represents the median, which is the middle value when the data is arranged in ascending order. For the variable "PSS", the box plot structure mirrors that of "SA", featuring the IQR, median, whiskers, and any specific outliers related to "PSS." Conducting a box plot analysis for both "SA" and "PSS" enables a comprehensive assessment of central tendencies and distributions for both variables. This analysis facilitates the identification of significant differences or similarities between the two variables.

**Table 9:** Result of Multivariate Tests Analysis

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | .869 | 1921.970 b | 2.000 | 579.000 | .000 |
| | Wilks' Lambda | .131 | 1921.970 b | 2.000 | 579.000 | .000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Hotelling's Trace | 6.639 | 1921.970[b] | 2.000 | 579.000 | .000 |
| | Roy's Largest Root | 6.639 | 1921.970[b] | 2.000 | 579.000 | .000 |
| PSS | Pillai's Trace | .120 | 1.609 | 46.000 | 1160.000 | .007 |
| | Wilks' Lambda | .883 | 1.614[b] | 46.000 | 1158.000 | .006 |
| | Hotelling's Trace | .129 | 1.618 | 46.000 | 1156.000 | .006 |
| | Roy's Largest Root | .089 | 2.244[c] | 23.000 | 580.000 | .001 |
| MA | Pillai's Trace | .188 | 2.320 | 52.000 | 1160.000 | .000 |
| | Wilks' Lambda | .819 | 2.344[b] | 52.000 | 1158.000 | .000 |
| | Hotelling's Trace | .213 | 2.368 | 52.000 | 1156.000 | .000 |
| | Roy's Largest Root | .160 | 3.561[c] | 26.000 | 580.000 | .000 |
| PSS * MA | Pillai's Trace | .667 | 1.096 | 530.000 | 1160.000 | .105 |
| | Wilks' Lambda | .444 | 1.096[b] | 530.000 | 1158.000 | .106 |
| | Hotelling's Trace | 1.004 | 1.095 | 530.000 | 1156.000 | .107 |
| | Roy's Largest Root | .546 | 1.196[c] | 265.000 | 580.000 | .041 |

a. Design: Intercept + PSS + MA + PSS * MA

b. Exact statistic

c. Statistic is the upper bound of F that provides a lower bound at the significance level.

Table 9 presents the results of various multivariable tests for a design involving four variables: the intercept, PSS, MA, and the interaction between PSS and MA (PSS * MA). These test statistics are utilized to determine the impact of each variable on the outcome. All these tests yielded a p-value of 0.000, signifying the significance of the intercept and its interactions with other variables. The p-values for these tests ranged from 0.001 to 0.007. Notably, while PSS has a significant effect, it is not as pronounced as the intercept. The p-values for these tests are uniformly 0.000, with MA exhibiting the most substantial effect. The interaction effect between PSS and MA has p-values ranging from 0.041 to 0.107, indicating its significance, although it is comparatively weaker than the main effects (PSS + MA). Multivariate tests confirm the overall model's significance, encompassing the intercept and its interactions with PSS + MA. The main effects (PSS + MA) are also highly significant. Although the interaction effect (PSS * MA) demonstrates some significance, it is less pronounced than the main effects."

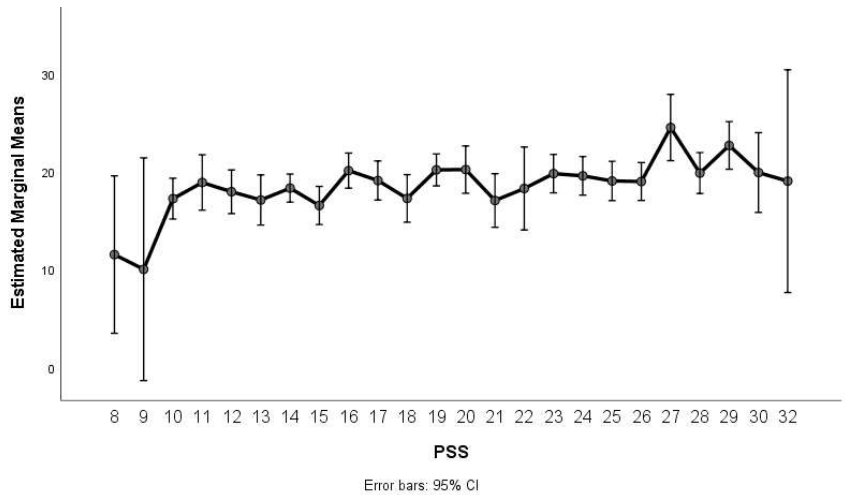


**Figure 6:** Estimated Marginal Means of PSS Variable

Figure 6 presents the marginal mean of "LE," which is calculated as the average of the mean values of "LE" across different categorical independent variables. Along this axis, each category or level of an independent variable is clearly labelled for easy identification. This axis represents the estimated marginal mean of "LE," and the corresponding mean values for each category of the independent variable are plotted, typically indicated by appropriate markers or points. This numerical metric holds significant importance in statistical analysis, particularly when working with independent categorical variables. It serves as a valuable tool for researchers, allowing them to assess the impact of these variables on the dependent variable (LE) while controlling for other factors.

**Table 10:** Tests of Between-Subjects Effects

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Corrected Model | LE | 12654.620[a] | 314 | 40.301 | 1.201 | .030 |
| | SA | 13850.307[b] | 314 | 44.109 | 1.484 | .000 |
| Intercept | LE | 60473.396 | 1 | 60473.396 | 1802.413 | .000 |
| | SA | 64629.317 | 1 | 64629.317 | 2174.722 | .000 |
| PSS | LE | 1686.325 | 23 | 73.318 | 2.185 | .001 |
| | SA | 738.388 | 23 | 32.104 | 1.080 | .362 |

| | | | | | | |
|---|---|---|---|---|---|---|
| MA | LE | 1258.425 | 26 | 48.401 | 1.443 | .073 |
| | SA | 2518.977 | 26 | 96.884 | 3.260 | .000 |
| PSS * MA | LE | 8988.676 | 265 | 33.920 | 1.011 | .453 |
| | SA | 9324.935 | 265 | 35.188 | 1.184 | .051 |
| Error | LE | 19459.789 | 580 | 33.551 | | |
| | SA | 17236.688 | 580 | 29.718 | | |
| Total | LE | 356084.000 | 895 | | | |
| | SA | 355323.000 | 895 | | | |
| Corrected Total | LE | 32114.409 | 894 | | | |
| | SA | 31086.994 | 894 | | | |
| a. R Squared = .394 (Adjusted R Squared = .066) | | | | | | |
| b. R Squared = .446 (Adjusted R Squared = .145) | | | | | | |

Table 10 provides a MANOVA test of the study, encompassing two dependent variables, namely "LE" and "SA", along with multiple independent variables, such as "PSS" and "MA," and their interaction denoted as "PSS*MA". For "LE", the corrected model reveals a Type III sum of squares of 12,654.620, with a mean square (df) of 314. The mean square (SD) is 40.301, and the F-statistic stands at 1.201, yielding a p-value of 0.030. This indicates a statistically significant model in predicting "LE". For "SA", the corrected model showcases a type III sum of squares amounting to 13,850.307, with a mean square of 314.109 (SD = 44.109). The mean square's F-statistic is 1.484, and it registers a statistically significant prediction for "LE". The intercept for "SA" stands at 64.629.317 (1 degree of freedom), with a mean square of 64.629.722 (2174.722) and a p-value of 0.000. This underscores the high predictiveness of the intercept for "SA". Regarding "PSS" and "MA", the table provides information on the interaction effect, including type III sum of squares, degrees of independence, squares, F-statistics, and p-values for "LE" (8988.676) and "MA" (33.920). The F-statistic for this interaction effect is 1.011, with a p-value of 0.453, indicating a lack of statistical significance ($p > 0.05$) for this interaction in predicting "LE". In contrast, the interaction effect for "SA" exhibits a type III sum of squares of 9324, with 265 degrees of freedom. The mean square is 35.188, and the F-statistic equals 1.184, with a p-value of 0.051. This suggests that the interaction effect for "SA" has borderline statistical significance, with $p \approx 0.05$. Finally, the table below presents the corrected total Type III sum of squares for error terms of both "LE" and "SA," affirming the statistical significance of both models. Notably, the main effects of "PSS" and "MA" emerge as significant predictors of "SA," while "MA" demonstrates borderline significance in predicting "LE".

## 6. RESEARCH CONCLUSION

This study investigated the problem-solving skills and chemistry learning experiences of undergraduate students and their impact on academic achievement. The findings of this study emphasize the crucial role of problem-solving ability in determining the academic success of undergraduate chemistry students. Through a comprehensive examination of the relationship between problem-solving skills (PSS) and academic performance, it has become evident that students with strong problem-solving skills exhibit a deeper understanding of chemical concepts and excel in their academic pursuits. The ability to approach and tackle complex challenges in chemistry allows students to bridge the gap between theoretical knowledge and practical application, enhancing their overall learning experience. Furthermore, this research has illuminated the influential role of pedagogical approaches in nurturing problem-solving skills among undergraduate chemistry students. Problem-based learning has emerged as a promising method to promote critical thinking and analytical reasoning, equipping learners with the tools to creatively address intricate chemical problems. Educators play a crucial role in cultivating problem-solving abilities through interactive and engaging teaching methodologies. They encourage students to actively participate in the learning process and foster their confidence in addressing novel scientific inquiries. In light of these insights, it is evident that an integrated approach to undergraduate chemistry education, with a substantial emphasis on the development of problem-solving skills, can significantly contribute to improved academic achievements and prepare students for successful careers in the field of chemistry. Moving forward, educational institutions and instructors must recognize the significance of problem-solving in the curriculum. They should incorporate innovative teaching strategies that stimulate students' problem-solving aptitude. Consequently, this study ensures that the upcoming generation of chemists will be fully prepared to address the ever-changing scientific challenges and make noteworthy contributions not only to the field of chemistry but also to the broader spectrum of scientific advancements.

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