iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** XII **Month of publication:** December 2025

DOI: https://doi.org/10.22214/ijraset.2025.76217

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

Assessing the Effectiveness of First-year Geodetic Engineering Student's Learning on Balancing Chemical Equations through Virtual Laboratories

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Abstract: ***Balancing chemical equations is one of the fundamental yet challenging concepts that first-year Geodetic Engineering students encounter as they develop their foundation in basic chemistry. With the objective to assess the effectiveness of a virtual laboratory in improving students' understanding of balancing chemical equations, as well as to determine the learning gains before and after the intervention, the researchers measured the changes in students' performance through a pre-test and post-test. Using a quantitative research design with a researcher-made assessment, the study aimed to capture how the virtual laboratory supported students' learning. Data were analyzed using descriptive statistics to determine the improvement in students' scores and their level of understanding of the topic. Findings revealed that the virtual laboratory contributed to better comprehension, as students showed increased accuracy in balancing chemical equations after the intervention. However, the limited number of respondents posed constraints on the generalizability of the results. The study suggests that future researchers should include larger groups of students and enhance virtual laboratory activities to further strengthen engagement and learning outcomes.***

Keywords: virtual laboratory, balancing chemical equations, learning effectiveness, geodetic engineers

I. INTRODUCTION

Inadequate laboratory equipment is one of the greatest challenges in the teaching and learning of chemistry. In response to these constraints, virtual laboratories have been proposed as a new solution, offering students computer-generated environments where they can perform experiments and view and examine data in a simulation environment. These tools mimic the critical aspects of the traditional laboratory, offering learners the opportunity to engage with scientific principles within a simulated and realistic online environment. This arrangement can be useful in balancing the theoretical and practical aspects of learning by providing students with a virtual lab that can resemble the actual hands-on experimentation. Vijayatheepan (2023) notes that the introduction of virtual laboratories is a breakthrough in the field of science education. Conventional methods of laboratory work can be limited by resource availability, safety requirements, and logistics. Educators can overcome these barriers with technological advancements that have facilitated a transition to more flexible, more accessible learning experiences. Virtual labs match the modern trends of employing technology to increase student motivation and the efficiency of learning by facilitating interactive and inclusive experimentation.

In the teaching of chemistry, foundational concepts hold primary significance. Chemistry is the main science that bridges the gap between physical and life sciences by studying the composition, properties, and changes of matter. This underpinning is especially pertinent to students studying disciplines like Geodetic Engineering, since the analysis of soil and rock properties, the study of water quality, or the evaluation of the stability of construction materials all require chemical principles to be used (Halkevych, 2025). The conceptual understanding of these concepts starts with fundamental skills, such as being able to describe chemical changes using balanced chemical equations correctly. Skills in balancing equations are essential, as these concepts contribute to the knowledge of stoichiometry, reaction outcome predictions, and compliance with the Law of Conservation of Mass (Hussain et al., 2023).

II. OBJECTIVES

This study aims to assess the effectiveness of virtual laboratories in enhancing students' learning on balancing chemical equations. It seeks to determine whether the use of virtual laboratory activities can improve students' understanding and proficiency in balancing chemical equations compared to traditional learning methods.

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It seeks to:

1) Determine the effectiveness of virtual laboratories in improving First-year Geodetic Engineering students' performance in balancing chemical equations in terms of accuracy.
2) Examine the First-year Geodetic Engineering students' perceptions of using virtual laboratories in learning chemical equations in terms of:
- Usability and
- Engagement.
3) Compare the learning outcomes of First-year Geodetic Engineering students who use virtual laboratories with those who use traditional learning methods.

III. MATERIALS AND METHODS

A. *Research Design*

This study undergoes quantitative research design to objectively measure the effectiveness of Virtual Laboratories in learning balancing chemical equations. The design serves as a procedural plan for answering the research question (Khanday & Khanam, 2023). Data was collected using survey questionnaires administered to a representative sample, and the resulting numerical data will be statistically analyzed to identify patterns, correlations, and measure outcomes relevant to the research objectives (Kharbach, 2023).

B. *Subjects of the Study*

This study used first-year students enrolled in the Bachelor of Science in Geodetic Engineering 1102 from the Alangilan campus of Batangas State University. These students were selected as participants because they are expected to demonstrate foundational knowledge in chemistry, and the use of virtual laboratories may play a role in enhancing their understanding. The setting provided an appropriate academic environment to assess the effectiveness of virtual laboratories as an alternative instructional tool in improving students' learning on balancing chemical equations.

C. *Data Gathering Instrument*

The researchers used a combination of standardized tests (Pre-Test and Post-Test) and survey questionnaires (Student feedback) as they provide a critical data source on both students' learning performance and their perceptions of the virtual laboratory.

Questionnaire. The study employed two primary data collection instruments: a researcher-developed assessment and a perception survey questionnaire. The researcher-developed assessment functioned as both the pre-test and post-test and comprised 10 items intended to evaluate students' foundational knowledge and proficiency in balancing chemical equations. Meanwhile, the perception survey questionnaire was utilized to assess the effectiveness of the virtual laboratory, specifically examining students' levels of engagement, the tool's efficiency, and the clarity with which the lesson was understood. Prior to administration, both instruments underwent content validation by the research adviser to ensure their accuracy, clarity, and suitability for the study's objectives.

Scoring of Responses. The perception survey responses were scored and interpreted using a Likert-scale format. Weighted mean scores were calculated to describe students' experiences, with values interpreted according to descriptors such as "Strongly Agree" and "Agree" to quantify the perceived effectiveness of the virtual laboratory. For the pre-test and post-test assessments, scores were derived from the frequency of correct answers and mean scores to evaluate improvements in student performance and learning gains.

Likert Scale Interval	Verbal Interpretation
4.00 - 3.26	Strongly Agree
3.25 - 2.51	Agree
2.50 - 1.76	Disagree
1.75 - 1.00	Strongly Disagree

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D. Data Gathering Procedure

After obtaining approval and validating the research instruments, the study was conducted with first-year Geodetic Engineering students, following the acquisition of informed consent. The procedure commenced with a pre-test to establish baseline knowledge, followed by the implementation of the virtual laboratory intervention. Upon completion, a post-test and perception survey were administered to assess learning gains and to evaluate students' experiences. The collected data were subsequently organized and analyzed to determine the effectiveness of the intervention.

IV. RESULTS AND DISCUSSION

This chapter contains the presentation, analysis and interpretation of data. The data were presented in textual form, arranged chronologically based on the order of presentation of the problems in this study.

Table 1. Students' response in Pre-test Questions

Post-Test Questions	FOCA	Percentage
1.What does it mean to balance a chemical equation?	22	88%
2. A virtual laboratory helps students learn balancing chemical equations by	25	100%
3. What does coefficient in a chemical equation represent?	19	76%
4. What is the main purpose of using a virtual laboratory in learning chemical reactions?	19	76%
5. Virtual laboratories are most useful for	19	76%
6. Which of the following steps is *not* part of balancing a chemical equation?	16	64%
7. What is the balanced form of this equation?	11	44%
8. Which of the following equations is correctly balanced?	12	48%
9. In the balanced equation 2Al + 3Cl2 → 2AlCl3, how many chlorine atoms are on the product side?	15	60%
10. Balance this equation: _Fe + _O2 → _Fe2O3	11	44%

Legend: FOCA - Frequency of Correct Answers

The pretest outcomes indicate that, though students have a fine theoretical background on the concepts of chemical equations, they do not have skills on balancing in practice. The poorest performing items are directly connected with balancing chemical equations, which is also justified by the main focus of the study to identify the possibility to enhance the procedural accuracy and the procedural understanding of students with the help of virtual laboratory simulations**.**

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

Table 1.1. Students' assessment in Post-test Questions

Post-Test Questions	FOCA	Percentage
1.What does it mean to balance a chemical equation?	25	100%
2. A virtual laboratory helps students learn balancing chemical equations by	25	100%
3. What does coefficient in a chemical equation represent?	24	96%
4. What is the main purpose of using a virtual laboratory in learning chemical reactions?	23	92%
5. Virtual laboratories are most useful for	21	84%
6. Which of the following steps is *not* part of balancing a chemical equation?	21	84%
7. What is the balanced form of this equation?	8	32%
8. Which of the following equations is correctly balanced?	8	32%
9. In the balanced equation 2Al + 3Cl2 → 2AlCl3, how many chlorine atoms are on the product side?	24	96%
10. Balance this equation: _Fe + _O2 → _Fe2O3	11	44%

Legend: FOCA - Frequency of Correct Answers

The item analysis reveals a pattern of student mastery and learning gaps in the post-test. High Proficiency (84%–100% Success) are items 1, 2, 3, 4, 5, 6, and 9 demonstrated high proficiency. Item 9, with a 96% success rate, is among the concepts that are well-understood by the majority of the students. Moderate Difficulty (44% Success) is item 10, which requires balancing the equation with a success rate of only 44%. This indicates a significant number of students struggled with this specific balancing question. Severe Learning Insufficiency (32% Success) are items 7 and 8 are the most difficult questions, both having a low success rate of only 32%. These items cover the concepts of identifying the balanced form of a reaction and identifying which equation is correctly balanced. The material covered by these two questions represents the highest priority for re-teaching, as over 60% of the students failed to answer them correctly.

Table 1.2 Mean Comparison Table of Pre-Test and Post-Test

Test	Sample (N)	Mean	St.Dev.	Min. Score	Max. Score
Pre-test	25	16.900	4.748	9	22
Post-test	25	19.500	7.087	9	25

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Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

The outcome of the assessment of the students regarding the engagement of the virtual laboratories is presented in table 3. The findings indicate that there is a high student engagement with the virtual laboratory as evidenced by the composite mean of 3.33 which is an interpretation of Strongly Agree. The capability of making learning enjoyable is detected by the strong agreement by students that the virtual laboratory keeps them interested and that they like to conduct experiments. The greatest weighted mean of 3.76 shows that students strongly agree that the virtual laboratory enhances their interest in the topic, which shows the strength of using the virtual laboratory to compel learners. Conversely, the lowest weighted mean of 3.08, which is still seen as Agree, demonstrates that the students also have positive attitudes towards their capacity to remain focused using the simulation. According to Makransky, G. et al., (2019), the addition of virtual laboratory simulation enhances student engagement, motivation and interest in acquiring scientific concepts. They found that students are more engaged and attentive when learning in virtual science environments, as this type of simulation offers interactive work, visual representation, and instant feedback. The comprehensive review by Heradio R. et al. (2016) has revealed that virtual and remote laboratories improve student motivation, engagement, and satisfaction within various learning settings. Their discussion revealed that virtual laboratories promote active student engagement because of the ability to manipulate variables, conduct experiments in a safe setting, and learn concepts on their own time.

Table 1.2.1 Pre-test Scores Per Question

R	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	1	1	0	1	0	1	0	0	1	0
2	1	1	1	1	1	0	0	0	1	0
3	0	1	0	0	0	0	0	0	1	0
4	1	1	0	0	0	0	0	1	0	0
5	1	1	0	0	1	0	0	0	0	1
6	1	1	0	0	1	1	0	0	0	0
7	0	1	1	1	1	1	0	0	0	0
8	1	1	1	1	1	0	1	1	0	0
9	1	1	0	0	1	1	1	0	0	0
10	1	1	1	1	1	1	0	0	1	0
11	0	1	1	1	1	0	0	1	0	0
12	1	1	1	0	1	0	0	0	0	0
13	1	1	1	1	1	1	0	0	0	0
14	1	1	1	1	1	1	0	0	0	0
15	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	0	0	1	0
17	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	0	1	1	1

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19	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	0	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	0	0	1	1	1	1
23	1	1	1	1	1	0	1	0	1	1
24	1	1	1	1	0	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1
CAPQ	22	25	19	19	19	16	11	12	15	11

Legend: R - Respondents, CAPQ - Correct Answer Per Question

The data from the pre-test questionnaire administered to first-year Geodetic Engineering students reveal that these students display a moderate level of understanding of balancing chemical equations at the beginning of the lesson. Item analysis shows that Q1 and Q2 received the highest number of correct responses, with 22 and 25 students answering correctly, respectively, reflecting a solid grasp of the foundational concepts. In contrast, Q7, Q8, and Q10 recorded the lowest correct response rates, indicating noticeable difficulties when students were faced with more complex balancing tasks. Overall, these results suggest that while the students have basic knowledge of balancing chemical equations, they encounter challenges with higher-order problem-solving. This highlights the importance of targeted instructional interventions, such as virtual laboratory activities, to further develop their comprehension and practical skills in this topic.

Table 1.2.2 Post-test Scores Per Question

R	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
1	1	1	0	0	1	1	0	0	1	0
2	1	1	1	1	0	0	0	0	1	0
3	1	1	1	1	1	1	0	0	1	0
4	1	1	1	1	0	1	0	0	1	1
5	1	1	1	1	1	1	0	0	1	0
6	1	1	1	1	1	1	0	0	1	0
7	1	1	1	1	1	1	0	0	1	0
8	1	1	1	1	1	1	0	0	1	0
9	1	1	1	1	1	1	0	0	1	0
10	1	1	1	1	1	1	0	0	1	1
11	1	1	1	1	1	1	0	0	1	0

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12	1	1	1	1	1	1	0	0	1	0
13	1	1	1	1	1	1	0	0	1	0
14	1	1	1	1	1	1	0	0	1	0
15	1	1	1	1	1	1	0	0	0	0
16	1	1	1	1	1	1	0	1	1	1
17	1	1	1	1	0	0	0	0	1	0
18	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1
21	1	1	1	0	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	0	1	1	1	1
24	1	1	1	1	0	0	1	0	1	1
25	1	1	1	1	1	1	1	1	1	1
CAPQ	25	25	24	23	21	21	8	8	24	11

Legend: R - Respondents, CAPQ - Correct Answer Per Question

The post-test questionnaire results indicate a noticeable improvement in students' knowledge and skills in balancing chemical equations following the virtual laboratory intervention. The perfect scores obtained in Q1 and Q2 demonstrate complete mastery of the foundational concepts. Additionally, the increased number of correct responses for Q3, Q4, Q5, Q6, and Q9 highlights a strengthened proficiency in addressing more complex balancing tasks. Despite scores remaining relatively lower in Q7, Q8, and Q10 (with 8 and 11 correct responses, respectively), the overall data show a clear improvement in students' understanding and practical abilities in the topic. These results suggest that the virtual laboratory intervention successfully facilitated the development of both conceptual knowledge and applied skills in balancing chemical equations.

Table 2. Students' Assessment in Terms of Usability of Virtual Laboratory

Usability of Virtual Laboratory	WM	VI
1. The virtual laboratory is easy to use and understand.	3.52	Strongly Agree
2. The virtual laboratory is easy to understand even without detailed instructions.	3.36	Strongly Agree
3. The virtual laboratory allows me to perform experiments independently.	3.68	Strongly Agree
4. The design and layout of the virtual laboratory make learning convenient.	3.68	Strongly Agree
5. The use of virtual laboratory helps me save time compared to traditional lab activities..	3.72	Strongly Agree
Composite Mean	3.59	Strongly Agree

Legend: WM - Weighted Mean, VI - Verbal Interpretation

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Table 2 presents the students' assessment in terms of the usability of virtual laboratories. Findings revealed a composite mean of 3.59, which is verbally interpreted as Strongly Agree. This indicates that the respondents perceived the virtual laboratory as highly usable and effective in supporting their learning needs. The consistently high ratings reflect that the platform is user friendly, accessible, and conducive to efficient laboratory engagement.

To further explain this, Statement 5 which states that the use of the virtual laboratory helps students save time compared to traditional lab activities obtained the highest weighted mean of 3.72. This suggests that students strongly agreed that virtual laboratories provide significant advantages in terms of time efficiency. This may imply that learners value how virtual labs reduce preparation time, minimize setup procedures, and allow faster completion of experiments. Supporting this, Fadda et al. (2022) found that virtual laboratory platforms increase learning efficiency because students can conduct experiments more quickly and revisit tasks without the constraints of physical materials. Similarly, Santos and Prudente (2022) reported that virtual laboratory environments enhance student performance by offering convenient and flexible access to experiments, making learning more efficient.

Meanwhile, Statement 2 which states that the virtual laboratory is easy to understand even without detailed instructions obtained the lowest mean of 3.36, though still verbally interpreted as Strongly Agree. This indicates that while the virtual lab is generally intuitive, some students may still benefit from clearer guidance or step by step instructions. This finding aligns with Nursing Students Perception Study (2024) which found that although students positively perceive virtual laboratory systems as user friendly, usability improves further when platforms include structured guidance and organized instructions. Additionally, Interactive Virtual Lab Media Study (2024) emphasized that the integration of supportive instructional features increases students' confidence and ability to navigate virtual experiments more effectively.

Table 3. Students' Assessment in Terms of Engagement of Virtual Laboratory

Engagement of Virtual Laboratory	WM	VI
1. Using a virtual laboratory keeps me interested in learning balancing chemical equations.	3.36	Strongly Agree
2. I enjoy performing experiments using the virtual laboratory.	3.28	Strongly Agree
3. The interactive features of the virtual laboratory make learning more fun.	3.16	Agree
4. Using the virtual laboratory made me more interested in learning balancing chemical equations.	3.76	Strongly Agree
5. I feel more focused when using virtual laboratory simulation.	3.08	Strongly Agree
Composite Mean	3.33	Strongly Agree

Legend: WM - Weighted Mean, VI - Verbal Interpretation

Table 3 shows the result of the students' assessment in terms of engagement of virtual laboratories. The results show a high level of student engagement with the virtual laboratory, as reflected in the composite mean of 3.33 interpreted as Strongly Agree. Students strongly agree that the virtual laboratory keeps them interested and they enjoy performing experiments, indicating its ability to make learning more enjoyable. The highest weighted mean of 3.76 indicates that students strongly agree that the virtual laboratory increases their interest in the topic, highlighting its effectiveness in motivating learners.

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On the other hand, The lowest weighted mean of 3.08, though still interpreted as Agree, shows that students also have positive perceptions regarding their ability to stay focused while using the simulation. Makransky, G. et al., (2019) found that incorporating virtual laboratory simulations increases students' engagement, motivation, and interest in learning scientific concepts. Their study showed that students are more focused and involved when using virtual science environments because these simulations provide interactive task, visual representation, and immediate feedback. Heradio R. et al., (2016) conducted an extensive review showing that virtual and remote laboratories enhance student motivation, engagement, and satisfaction across different learning environments. Their analysis highlighted that virtual labs encourage active participation by allowing students to manipulate variables, perform experiments safely, and explore concepts at their own pace.

Table 4. Students' Assessment in Terms of Effectiveness of Virtual Laboratory

Effectiveness of Virtual Laboratory	WM	VI
1. The virtual laboratory helps me understand the process of balancing chemical equations.	3.68	Strongly Agree
2. I can recall and apply the concepts I learned from the virtual laboratory.	3.6	Agree
3. My accuracy in balancing chemical equations improved after using the virtual laboratory.	3.56	Strongly Agree
4. The virtual laboratory enhances my problem-solving skills in balancing chemical equations.	3.56	Strongly Agree
5. The virtual laboratory is an effective tool for improving my learning performance.	3.6	Agree
Composite Mean	3.6	Strongly Agree

Legend: WM - Weighted Mean, VI - Verbal Interpretation

Table 4. shows an evaluation of the students in the use of the virtual laboratory on the effectiveness of learning how to balance chemical equations. The maximum weighted mean value is 3.68, which indicates that students strongly agree that the virtual laboratory assists students in learning the balancing process. In the meantime, the weighted average of the lowest mean is 3.56, which again is covered by "strongly agree," showing that there are positive perceptions even in the least rated spheres. In general, the composite mean of 3.60 (Agree) demonstrates that the students tend to think that the virtual laboratory is a good tool in order to improve their learning. The result indicates that the improvements reported in Table 4 reflect the potential of RRLAs to assist students in comprehending the ideas of radioactivity more easily by giving them more easy and fascinating means of investigating the subject. In this regard, Karpudewan and Chong (2020) discovered that remote laboratory tools help students learn because they let them interact with simulations, repeat exercises, and see ideas that are usually difficult to explain in a face-to-face setting. Students' comprehension and motivation are progressively rising because they have access to the flexibility and clarity that these digital activities provide.

V. CONCLUSIONS

In connection with the findings of the study, the following conclusions were drawn:

1) The first-year Geodetic Engineering students found it challenging to solve difficult and complex balancing chemical equations even though they already have a grasp of the foundational concept and balancing processes of the subject.

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2) Students rated the virtual laboratory with high satisfaction, indicating that the platform is easy to use, engaging, and supportive of independent learning.
3) Improvement in students' performance and positive feedback on the platform indicate that the virtual laboratory is practical, accessible, and effective in assisting students to strengthen their understanding of chemistry concepts.
4) The findings suggest that virtual laboratories are effective assistance tools for studying that enhance learning outcomes, increase engagement, and support the development of scientific skills, especially in environments with limited resources and large class sizes.

VI. RECOMMENDATIONS

In light of the findings and conclusions of the study, the following recommendations are hereby presented:

1) Conduct further research to identify specific factors that cause students to continue struggling with balancing chemical equations, especially items requiring multi-step reasoning and recognition of properly balanced equations.
2) Investigate potential obstacles that prevent students from fully engaging with virtual laboratories, such as unfamiliarity with simulations, varying prior experiences, or the need for more explicit instructional guidance.
3) Examine the effectiveness of a blended learning approach that integrates virtual laboratories with traditional teaching methods to enhance student engagement and understanding.
4) Consider implementing a longer intervention period in future studies to better evaluate long-term retention and comprehension related to balancing chemical equations.
5) Broaden the scope and refine future research efforts to gain a clearer and more comprehensive understanding of how virtual laboratories can be optimized to support chemistry learning.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

ACKNOWLEDGEMENT

The researchers would like to express their deepest gratitude to all the individuals who have contributed to the successful completion of this research study. We would like to acknowledge all the support and contribution of the following:

To our Chemistry Professor, **Mr. Bryle A. Armeza**, for his continuous support, guidance and patience, and for sharing with us her knowledge that significantly contributed to the completion and success of our research.

To the **respondents**, for generously giving their time and effort to participate in our study, expressing their willingness to share their perspectives and experiences through honest responses.

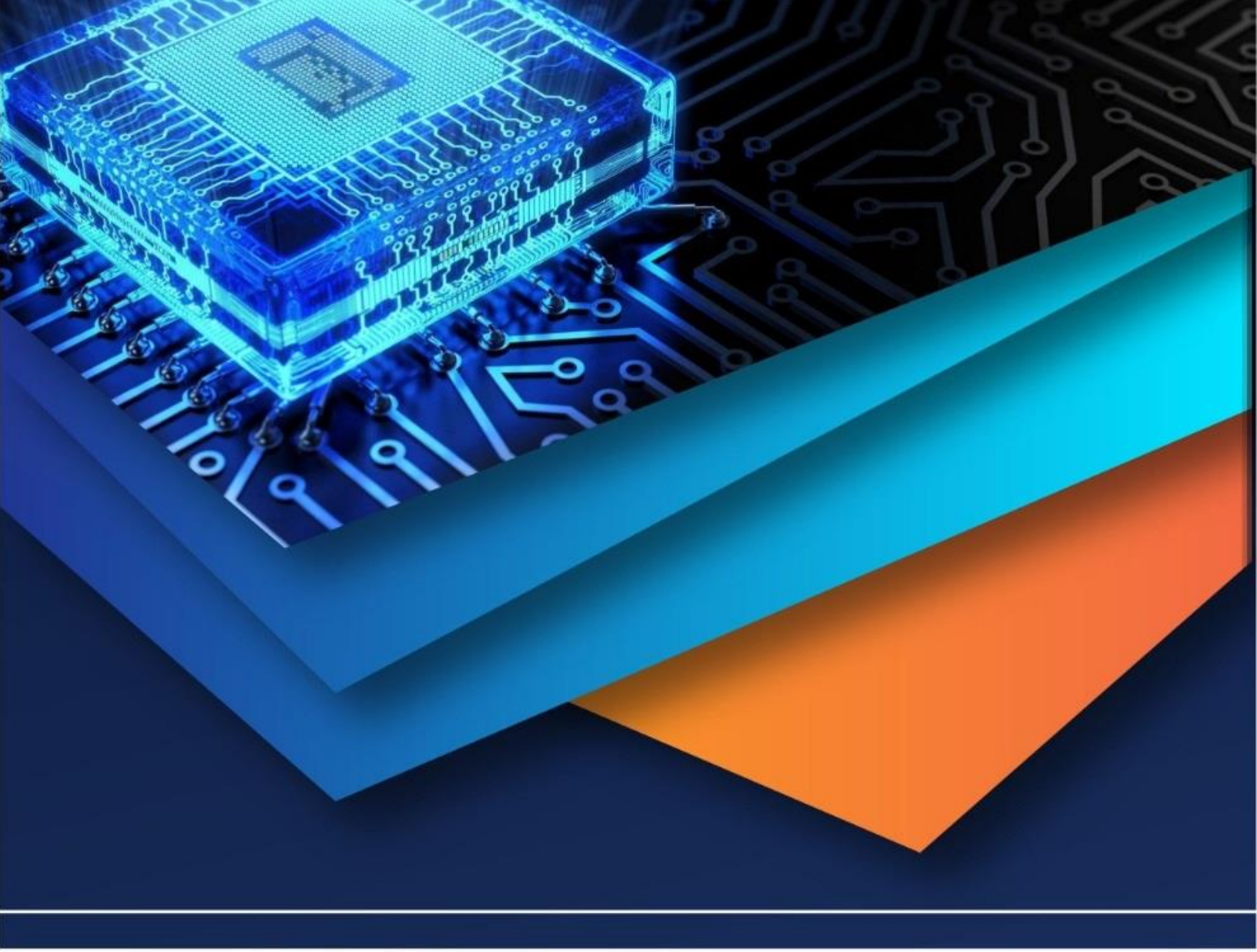
To our fellow **Spartans**, for their unwavering support and assisting us in gathering data for this study

To our beloved **parents**, who have always been the inspiration behind all our endeavors, for providing us with unconditional love, constant encouragement and support that helped us finish this research.

Lastly, to **Almighty God**, who has given us the gift of life with the strength of mind and body to finish this research. To the strength He gave us to overcome all of the obstacles we encountered while creating this study. His countless blessings have led us to the success we never thought we would have. Without whom, nothing would be possible.

This study would not have been possible without the invaluable contributions and support of the individuals mentioned above. We extend our heartfelt gratitude to everyone who became part of this study. Thank you very much for your support and assistance.

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