# The impact of teaching stoichiometry using Phet simulation on the learning outcomes of grade 10 students in chemistry

# تأثير تدريس علم الحساب الكيميائيّ باستخدام محاكاة PHET على نتائج التّعلّم لطلاب صف العاشر(الأوّل الثّانويّ) في مادة الكيمياء

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**Abstract**

There has been an increasing need for strategies that increase teaching effectiveness while encouraging students to participate more actively in the context of changing educational practices. The purpose of this study was to investigate how well Phet Interactive Simulations teach stoichiometry and enhance students' chemistry performance in comparison to more traditional teaching methods. For three weeks, 59 Grade 10 students from a southern suburb mixed private school in Beirut, Lebanon participated in the study, which used a quasi-experimental design. Twenty students were in the control group, which received traditional instruction, and 39 students were in the experimental group, which received instruction based on Phet simulations. The study included the use of pre- and post-tests as well as primary quantitative data. Phet simulations considerably improved students' comprehension of stoichiometry, according to statistical analysis, and the experimental group's performance

(1) ماجستير بحثي في تعليم الكيمياء للمرحلة الثّانويّة- أستاذ كيمياء في التّعليم الثّانوي - باحث تربويّ متخصّص في طرائق تدريس الكيمياء للمرحلة الثّانويّة.

showed significant improvements in their learning outcomes. The findings, which show a p-value of 0.026, validate that Phet simulations performed better than traditional methods, indicating that they are a suggested tool for teaching difficult chemistry subjects.

**Key words**

Phet Interactive Simulations, Stoichiometry, Chemistry Education, Simulation-based Learning, Educational Technology

**الملخّص**

لقد زادت الحاجة إلى استراتيجيات تعزّز فعالية التّعليم بينما تشجّع الطّلاب على المشاركة بشكل أكثر نشاطًا في سياق التّغيّرات في الممارسات التّعليميّة. كان هدف هذه الدّراسة هو التّحقيق في مدى فعالية محاكاة Phet التّفاعليّة في تعليم علم الحساب الكيميائيّ وتحسين أداء الطّلاب في مادة الكيمياء مقارنة بأساليب التّدريس التّقليديّة. لمدة ثلاثة أسابيع، شارك 59 طالبًا من الصّف العاشر من مدرسة خاصّة مختلطة في ضواحي بيروت الجنوبيّة في الدّراسة التي استخدمت تصميمًا شبه تجريبيّ. كان هناك 20 طالبًا في مجموعة التّحكّم، التي تلقت التّعليم التّقليديّ، و39 طالبًا في المجموعة التّجريبيّة التي تلقّت التّعليم باستخدام محاكاة Phet. شملت الدّراسة استخدام اختبارات قبليّة وبعديّة، بالإضافة إلى البيانات الكمية الأساسيّة. أظهرت التّحليلات الإحصائيّة أنّ محاكاة Phet قد حسّنت بشكل كبير من فهم الطّلاب لعلم الحساب الكيميائيّ، وأظهرت نتائج أداء المجموعة التّجريبيّة تحسّنًا كبيرًا في نتائج التّعلّم. وأكّدت النّتائج، التي أظهرت قيمة p تبلغ 0.026، أنّ محاكاة Phet كانت أكثر فعالية من الأساليب التّقليديّة، ما يشير إلى أنّها أداة موصى بها لتدريس المواضيع الكيميائية الصّعبة.

**الكلمات المفاتيح:** محاكاة Phet التّفاعليّة، علم الحساب الكيميائيّ، تعليم الكيمياء، التّعلّم المعتمد على المحاكاة، التّكنولوجيا التّعليميّة.

## Chapter I: Introduction

The topic examines the role of technology in modern education, particularly how interactive tools like Phet Simulations can enhance learning outcomes.

Traditional teaching methods, which frequently fail to properly engage students, are a concern for education systems around the world, including Lebanon. With the help of these interactive resources, students can investigate difficult ideas through practical applications, providing a dynamic learning environment. Teachers can create a more dynamic and cooperative learning environment that promotes critical thinking and problem-solving abilities by incorporating such technologies into the curriculum. This change not only makes learning more interactive, but it also gets students ready to use what they've learned in the real world. In the end, integrating technology into the classroom can result in better academic achievement and a more thorough comprehension of the material.

The use of technology in the classroom has changed traditional teaching strategies over the last few decades, moving away from lecture-based, passive learning and toward more dynamic, engaging and student-centered methods. A notable advancement in this revolution may be seen in tools such as Phet Simulations, which provide dynamic, experiential learning opportunities that let students engage with complicated scientific concepts in real time.

In the context of Lebanon's education system, which faces challenges like outdated methodologies and a lack of student engagement, this technological shift holds promise. By integrating advanced simulation tools, educators can better captivate students' attention, deepen their understanding, and provide real-world applications of abstract concepts like stoichiometry in chemistry. These innovations not only make learning more interactive but also promote critical thinking, problem-solving, and analytical skills needed in the 21st century.

The goal of this quantitative-method study is to assess the overall impact of teaching chemistry concepts using simulation tools on students learning outcomes, and ultimately mastery of chemistry concepts, starting with the fact that one of the most basic requirements of teaching and learning chemistry is the engagement of students in the learning process. The integration of technology (simulation tools) helps in the development of the 21 century skills and competences. In their article, Sam Ramaila1 & Anwar Junior Molwele highlighted that: In the teaching and learning of life sciences, technology integration was thought to support the development of 21st century skills and capabilities. Teachers specifically mentioned that using technology helps students develop abilities including problem-solving, communication, critical thinking, teamwork, and computational thinking. Furthermore, it was believed that integrating technology into the classroom created an engaging atmosphere that improved students' academic performance and motivation. (Ramaila & Molwele, 2022)

Chemistry is an active, evolving science that has vital importance to our world in both the realm of nature and the realm of society, where knowledge and understanding of its concepts depends on the perception of the chemical and physical phenomena.

A key idea in chemistry, stoichiometry. The words “stoicheion,” which means element, and “metron,” which means measure, combine to form the term “stoichiometry,” which has its origins in ancient Greek. The fundamental idea of stoichiometry, which is all about measuring and quantifying the components and compounds that contribute to a chemical reaction, is clearly shown by this language history. In short, stoichiometry aids chemists in determining the precise amounts of starting materials required as well as the amounts of products produced. Stoichiometric calculations serve as the cornerstone of chemical science, providing a crucial framework for understanding and predicting the outcomes of chemical reactions. (Hussain, Safdar, & Özarslan., 2023)

Stoichiometry allows students to forecast the quantities of reactants and products in chemical reactions by bridging the gap between theoretical knowledge and quantitative problem-solving. However, the abstract nature of the subject and the mathematical calculations required make it difficult for many grade ten students to comprehend stoichiometric principles. This has led to lower academic achievement in chemistry and widespread misconceptions and a lack of confidence in learning chemistry. (Musyoki, (2022)).

Technology integration in science instruction has improved student engagement and conceptual understanding in recent years, with encouraging outcomes. The Phet Interactive Simulations, created by the University of Colorado Boulder, is one such resource that provides interactive and visual experiences to improve students' understanding of difficult scientific ideas.

The Phet Interactive Simulations project at the University of Colorado Boulder, which was founded in 2002 by Nobel Laureate Carl Wieman, produces free interactive scientific and math simulations. Based on a wealth of educational research, Phet simulators involve students in an easy-to-use, game-like setting where they may learn by doing. (Boulder), 2025)

Students may find it difficult to grasp stoichiometry, a crucial chemical topic, because of its intricate mathematical ideas. It is frequently difficult for traditional teaching techniques, such as lectures and textbook exercises, to hold students' attention and promote in-depth comprehension. Even if these methods have value, they might not always give students the interactive, practical experience they want to completely understand the subject.

Educational technology has made it possible to improve the learning experience in innovative ways in recent years. In particular, Phet simulations provide a visual and participatory way to explore scientific ideas. These simulations provide students a greater understanding of concepts like stoichiometry by letting them change variables and see the outcomes in real time. Students can investigate and visualize chemical topics in a hands-on way by using interactive simulations like Phet, which could provide an engaging and helpful option.

By contrasting the learning outcomes of students who use simulations with those who rely on traditional methods of teaching, this study investigates how well Phet simulations teach stoichiometry to grade 10 students. The objective is to investigate whether using these simulation resources might help students learn stoichiometry in a more interesting and efficient manner.

## 1.1 Statement of the Problem

Today, in Lebanon, it is a fact that conventional or traditional learning is no longer deemed to meet the needs of students. From the pandemic situation passing to the financial ones and even the social class inequality between regions, many causes have negatively affected education and the ways of learning in Lebanon, and hence Lebanon's education system has been severely harmed (Abourjeili, 2020).

For many students in grade 10, stoichiometry is still a difficult subject, despite its significance in the study of chemistry. Traditional methods of teaching, such as lectures, and textbook exercises, frequently fall short of capturing students' attention and may not provide them enough chances to visualize and engage with the difficult ideas being covered. Because of this, students could find it difficult to fully comprehend stoichiometric principles, which are crucial for understanding more complex chemical concepts.

With an increasing integration of technology in the classroom, interactive resources like Phet simulations have the potential to enhance student learning outcomes. These dynamic, practical learning experiences offered by these simulations may improve students' comprehension and application of stoichiometry. Nevertheless, not much research has been done on how well Phet simulations work to enhance students' comprehension and performance in stoichiometry, especially when compared to more traditional methods of teaching.

### 1.2 Purpose of the Study

The purpose of this study is to investigate how students' understanding and achievement are impacted when stoichiometry is taught via Phet simulations. The objective is to determine whether interactive simulations, as opposed to traditional teaching techniques, may improve students' understanding of stoichiometric concepts. The study will attempt to determine whether Phet simulations enhance students' problem-solving skills and overall learning outcomes in stoichiometry by comparing the outcomes of students who use these simulations with those who are taught in the traditional way. This study also helps to provide insight into the potential for improving science education through the use of modern technology into the curriculum. The following research question and hypothesis were proposed on the basis of the preceding.

### 1.3 Research Question

1. How does the use of Phet simulations in teaching stoichiometry impact grade 10 students' understanding and performance in chemistry compared to traditional teaching methods?

### 1.4 Research Hypothesis

The exploration of simulation-based learning methods in chemistry teaching reveals a significant relationship between instructional strategies and student outcomes. By focusing on the independent variable “Phet simulation”, this study aims to observe its direct impact on both grade 10 students’ understanding of stoichiometry and their overall performance in chemistry. The use of interactive simulations is expected to enhance students’ conceptual comprehension and problem-solving skills, potentially leading to improved academic outcomes and more positive attitudes toward learning chemistry.

- **Independent Variable (IV):** Teaching method—simulation-based (Phet simulation-based learning) vs. traditional.
- **Dependent Variable (DV):** Student’s outcome

**Hypothesis $H_1$:** The use of simulation-based learning has a positive influence on students out comes compared to traditional teaching methods.

**Null hypothesis $H_0$:** The use of simulation-based learning method does not influence students’ outcomes compared to traditional teaching methods.

## Chapter II: Literature Review

### 2.1 Theoretical framework

The use of interactive simulations to improve student learning, especially in complicated disciplines like stoichiometry, is supported by a number of important educational theories, which form the basis of this work. For that this study is grounded by: the cognitive load theory, experiential learning theory, and constructivism.

1. **Constructivism** (Piaget, Vygotsky): Suggests that students actively acquire knowledge through social interactions and experiences. Students learn best when they are able to manipulate and experiment with concepts in a hands-on setting, according to Piaget. (Piaget, 1952).Vygotsky highlighted the importance of social interaction and the Zone of Proximal Development (ZPD) in education, where students gain from working together and receiving advice from teachers or peers who possess greater knowledge. (Vygotsky, 1978). This theory is supported by Phet simulations, which offer an interactive environment for students to experiment visually with stoichiometric ideas. Students can actively build their understanding of stoichiometry by investigating the links between reactants and products in chemical reactions through these simulations.

2. **Experiential Learning Theory** (Kolb): The experiential learning cycle developed by Kolb places a strong emphasis on learning by doing. Students move through four phases in this model: active exploration, abstract conception, reflective observation, and tangible experience. (Kolb, 1984).Phet simulations give students the opportunity to participate in concrete activities, which supports Kolb's experiential learning cycle. Students increase their grasp of stoichiometry by participating in the active experimentation phase, which involves experimenting with various variables and viewing the results in real-time.

3. **Cognitive Load Theory** (Sweller): According to the

cognitive load theory, students' ability to comprehend information is limited. Cognitive overload can result from traditional teaching approaches that overload students with information when they are learning complicated subjects like stoichiometry. (Sweller, 1988).Phet simulations provide a visual and interactive presentation of these ideas, which reduces cognitive load. The simulations reduce cognitive overload by helping students understand the abstract ideas of stoichiometry by letting them change variables and see results right away.

Several studies in chemistry theory and practice have looked into the problems students face in appropriating objects of knowledge related to chemistry ideas. Similarly, research has been conducted on the use of simulation-based learning in the teaching of most chemistry topics.

## 2.2 Conclusion

- Constructivism offers a solid theoretical basis for the study's use of Phet simulations. The simulations' interactive and practical engagements provide support to the idea that students might get a deeper and more significant understanding of stoichiometry by actively participating and working together in groups. The theory backs up the idea that students' comprehension and performance in chemistry will be enhanced by employing Phet simulations.
- Kolb's theory supports the idea that allowing students to actively engage with the material will help them grasp stoichiometry more deeply. Students can progress through

Kolb's experiential learning cycle by using Phet Simulations to see stoichiometric ideas in action. The study's justification of the use of Phet Simulations is strengthened by this link to experiential learning, which emphasizes how learning by doing can result in better learning outcomes and a deeper conceptual understanding.

- The use of Phet Simulations in the study is justified by Cognitive Load Theory, which explains how these resources reduce mental strain and improve students' ability to concentrate on comprehending stoichiometric concepts. Phet Simulations help students better understand abstract topics by lowering cognitive overload, which enhances learning results. The study builds on this idea by arguing that students who are taught using simulations will outperform those who are taught through traditional methods.

## 2.3 Related studies

### 2.3.1 Concept of Chemistry

The notion of "central science" is frequently applied to chemistry. Its significance to every other science is where it gets its name. One of the most significant fields of study in science is chemistry. The study of matter's structure, composition, and transformations is known as chemistry. Everything that is mass-containing and takes up space is considered matter. Like all scientific disciplines, chemistry is a process that aims to organize and simplify. Each thing we might think of is a distinct bit of matter, and there are many different kinds of matter. In addition to matter's composition, chemistry also studies matter's structure—or how its constituent parts interact with one another. ( Myers, 2003)

### 2.3.2 Introduction to Stoichiometry and Its Importance in Chemistry Education

One of the most crucial topics in general chemistry is stoichiometry. Usually, it is introduced after talking about unit conversions and atom components. Although it's not hard, the word's complicated sound turns off a lot of students. This makes it possible to introduce it as "mass relations." It relates to the masses of reactants, products, and components in a chemical reaction

This field is important in chemistry in different lessons such as balancing chemical equations, determining the limiting reactant, and calculating theoretical yields (Helmenstine, 2023)

### 2.3.3 Challenges in Teaching Stoichiometry

A study under the title of Recurrent Difficulties: Stoichiometry problem-solving was done in January 2018 showed that: Lack of comprehension of the mole concept, inability to balance chemical equations, use of inconsistent stoichiometric relationships, identification of the limiting reagent, determination of theoretical yields, and identification of substances in excess were the six main challenges found in the findings. In contrast to the traditional lecture approach, the study also discovered that problem-solving education was successful in resolving the issues that were found. It was highly advised that chemistry teachers examine and comprehend the challenges faced by their students in order to help them develop into competent and self-assured problem solvers. (Shadreck & Ochonogor, 2018)

### 2.3.4 Simulation-Based Learning in Education

The study of Samar Thabet Jallad aimed to aimed to examine the effectiveness of simulation-based learning on the educational practice of communication skills, satisfaction, and self-confidence among undergraduate nursing students. The results showed that: Among first-year nursing students (n = 112) who took part, 91.1% expressed great satisfaction with their simulation-based learning experiences. The posttest showed increased mean scores for self-confidence, student satisfaction, and communication skills. The practices of communication skills, satisfaction, and self-confidence were found to be suggestively correlated with simulation-based education. (Jallad, 2024)

In 2023, a study done on a sample of 42 undergraduate students studying International Relations at a university in Northern Colombia. The purpose of this study was to look into how Simulation-Based Learning (SBL), particularly in the context of the Model United Nations (MUN), might improve academic performance and foster critical thinking. Results showed that using simulations greatly increased students' comprehension, which in turn produced better learning results. ( Rico, Pacheco, Pabon, & Portnoy, 2023)

Another study done in 2018; supports the expanded usage of computer simulations in lab courses as teaching tools. The study's hypothesis was that students may be encouraged to learn analytically and creatively by using the time they would have saved by playing with realistic computer simulations. (Whitworth, Leupen, Rakes, & Bustos, 2018)

Among 142 chemistry students, 134 physics students, and 12 teachers, a study conducted in Kayonza District, Rwanda. The study addressed common misunderstandings about chemistry and physics. Researchers noted in their results that the abstract nature of physics and chemistry topics was successfully diminished by simulation-based learning. The mean scores of both subjects significantly improved between the pre- and post-tests, with the post-test findings clearly demonstrating an advantage. ( Iyamuremye, et al., 2023)

### 2.3.5 **Phet Simulations in Chemistry Education**

Evangeline Omoy in his article:" Phet Interactive Simulations: A Tool in Improving Academic Performance of Grade 10 Students in Balancing Chemical Equations" which was published in 2023 in Philippines, evaluated how well the Phet interactive simulation worked as a tool to help students improve their academic performance in the fourth quarter of grade 10 science, specifically in the area of balancing chemical equations, which is the least mastered skill. The results showed that it was clear that using Phet interactive simulations was a useful strategy for improving students' academic achievement. It is a useful intervention or remediation tool for helping students become proficient in solving equations. This suggests that Phet interactive simulation is a useful tool for improving students' proficiency in balancing chemical equations, which in turn improves academic achievement. (Omoy, 2023)

The impact of Phet interactive simulations on students' perceptions and learning outcomes in a General Chemistry II course at the City College of New York was investigated in the study "Examining the Use of Phet Simulations on Students' Attitudes and Learning in General Chemistry II" by Issa I. Salame and Jana Makki (2021). 158 students who had used Phet simulations during their lab sessions participated in the study. The study revealed that students' attitudes and perspectives regarding learning chemistry were generally improved by Phet simulations. The simulations, according to the students, helped them acquire a conceptual comprehension of chemical concepts and content. It has been discovered that Phet simulations assist students to learn and comprehend complex ideas that are frequently difficult to grasp in traditional laboratory settings. (Salame & Makki, 2021)

Another study done in 2024, evaluated the effectiveness of a guided inquiry learning model integrated with Phet simulations in enhancing students' critical thinking abilities and comprehension of reaction rate concepts. The results showed that students using Phet simulations for guided inquiry significantly outperformed students in traditional discovery learning environments in terms of both critical thinking and conceptual knowledge. These results highlight how simulation-supported guided inquiry can be used to build a dynamic and captivating learning environment that encourages deeper cognitive processing and retention. (Drastisianti, Dewi, & Alighiri, 2024)

Similarly, Ganasen and Shamuganathan (2017) highlighted the role of Phet in addressing misconceptions in chemical equilibrium. In their article:" The Effectiveness of Physics Education Technology (Phet) Interactive Simulations in Enhancing Matriculation Students' Understanding of Chemical Equilibrium and Remediating Their Misconceptions". According to the study's findings, the students in the treatment group outperformed the students in the comparison group in terms of achievement. Additionally, fewer students in both groups had misconceptions, although the experimental group outperformed the comparison group. ( Ganasen & Shamuganathan, 2017)

## 2.4 Summary

The literature review emphasizes the theoretical underpinnings of constructivism, experiential learning, and cognitive load theory—three important educational theories—that support the use of Phet simulations in stoichiometry instruction. The goals of employing interactive simulations to enhance student outcomes are in line with these theories, which place an emphasis on active involvement, experiential learning, and lowering cognitive overload.

The review also covers a number of studies that have investigated the efficacy of simulation-based learning in different educational contexts. These studies show how simulation technologies, such as Phet, have enhanced chemistry students' understanding, problem-solving abilities, and engagement. Phet simulations' capacity to improve academic performance is further supported by specific research on their use in chemistry education, particularly in areas like understanding abstract concepts and balancing chemical equations.

This literature offers a convincing rationale for using Phet simulations in your study, arguing that they can enhance students' learning results overall and assist in addressing the challenges they encounter while comprehending stoichiometry. The study aims to bridge the gap between more interactive, student-centered learning experiences and traditional teaching methods by implementing Phet simulations.

## Chapter III: Methodology

### 3.1 Introduction

This study is aimed at determining the impact of teaching stoichiometry using Phet simulation on students learning outcomes. This chapter presented a general outline of the methodology to be used in conducting the study.

### 3.2 Methodology Selected

This study will employ a **quantitative approach** to assess and investigate the relationship between two variables: the teaching method (Phet simulations vs. traditional teaching) and students' outcome in stoichiometry.

An essential component of evidence-based decision-making is quantitative research. Its significance is unambiguous: quantitative approaches offer empirical rigor, allowing practitioners (business), policymakers (government), and preachers (academic) to extract useful insights from data. (Lim, 2024)

### 3.3 Sample

The study sample was selected using the purposive sampling method, which is one of the types of non-probability samples. Purposive sampling also called judgment sampling enabled focused selection, ensuring that the participants were well-suited to answering the study questions at hand ( Etikan, Musa, & Alkassim , 2016,).

The current study's participants were students from my class, divided into three grade 10 sections (of total number 59 students.). The study was carried out in a mixed private high school in the academic year 2024-2025; the school's name will not be mentioned due to ethical considerations. Chemistry is the main topic of the study. The school offers the Lebanese curriculum in Arabic and English for students in kindergarten through grade twelve. The school administration granted all approvals for the study's application. Each student's name and academic standing will be kept private thanks to the dedication to confidentiality, which enables them to concentrate on their studies undisturbed and without influencing their final grades Students in grade 10 vary from 15 to 16 years old. They were divided into a one control group (20 students) and two experimental groups (39 students). Both groups were specifically chosen to meet the goals of the study and come from the same socioeconomic background. The educational level of students at the school does not vary significantly from section to section, providing a more controlled environment in which to perform the study. With this kind of sample, the researcher can choose participants according to particular traits that support the study's objectives. In this case, the homogeneity of the academic levels of the two groups served as the basis for student selection. This kind of sample offers a thorough grasp of the phenomenon under study in the particular context of the study, despite the fact that it could restrict or limit the generalizability of its results.

### 3.4 Research Design

This study used a quasi-experimental control group design (Cambell & Stanley, 1963), with a pre-test, post-test. Both the experimental group and the control group were taught differently. Two groups were used in the study: the control group (CG) and the experimental group (EG) for the students in grade 10, The control group (CG) was taught concepts using the traditional method ($X_0$), while the experimental group (EG) was exposed to the Phet simulations teaching as treatment (X). The quantitative data collected from the post-test were analysed using SPSS.

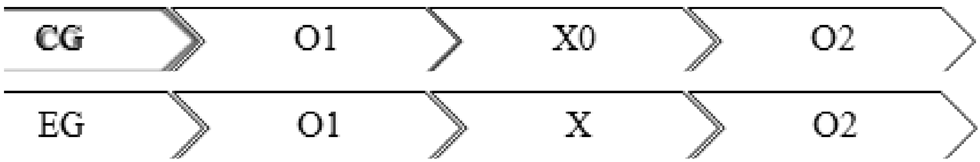


**Figure :1 Research design Diagram**

**Legend:**

- EG1 = Experimental Group
- CG = Control Group
- X= Phet simulation-based learning
- X0= Traditional Method of learning
- O1=pre-test
- O2 = post-test

### 3.5 Procedure

Both the control and experimental groups were taught by the researcher, a chemistry teacher with many years of experience and an excellent relationship with his students.

For three weeks starting from 7th March, the students in grade 10 were taught the concepts of stoichiometry in two groups (control group (CG) and the experimental group (EG) through 50-minute sessions held three times a week. The control group (CG) learned the concepts of stoichiometry: stoichiometric mixture, non-stoichiometric mixture limiting and excess reagent using traditional learning such as textbooks, whiteboard explanations, PowerPoint presentations, and PDF resources), while the experimental group (EG) learned the same concepts using Phet-simulation and the white board).For both groups the same educational content was delivered but with different learning strategies in order to effectively compare the two methods and their effects on students' outcome. Each idea was explained in great detail in this lesson, which was then followed by practice exercises and sample problems.

Before the intervention, the researcher gave the students introductory notes. To help students feel at ease and confident utilizing the program, these notes helped them on how to use the Phet simulation platform as well as provided troubleshooting advice for typical technical problems.

Students in the experimental group participated in nine sessions where they were split up into groups and used tablets to work with the Phet simulation under the guidance of the lecturers. They examined various stoichiometric ideas simulation in real life. Throughout the lessons, the teacher led the class, explaining everything and promoting group discussions following each simulation exercise. The 50-minute session was broken down as follows: the teacher introduced the topic for around 10 to 15 minutes, and then students engaged with the simulation for 25 to 30 minutes. This gave them a chance to explore the concepts in a dynamic, visual setting. A debriefing and group discussion are then held to make sure everyone understood and to clear up any misunderstandings that might have occurred during the simulation.

Following these three weeks the post test was held.

The assessment's results were examined to determine if the Phet simulation-based method and traditional stoichiometry learning produced significant differences in learning outcomes. Furthermore, the information gathered was intended to provide light on the teaching methods that helped students grasp stoichiometry principles more deeply.

### 3.6 Research instrumental tool

The instruments used are:

- Pretest.
- Post (achievement) test.

#### 3.6.1 Pretest

The teacher used their average grades in term 1 and the formative assessments that the students underwent as comparison data to show that these sections are similar and homogeneous, and this was referred to as the pre-test. This method enabled the teacher to create a baseline for comparison, guaranteeing that the chosen issues could be evaluated cohesively.

### 3.6.2 Post (achievement) test

Following the lesson and the intervention, the students in both groups completed the post-test. The purpose of this test is to evaluate the student's academic performance in the selected lesson. As a result, multiple Bloom's taxonomy levels will be tested. One of the most important ways to evaluate students' academic performance and comprehension of the subject matter is to provide a post-test after instructional interventions. Different levels of Bloom's taxonomy can be used by educators to assess students' application, analysis, and synthesis skills in addition to their retention of knowledge. ( Bloom, 1956)

The following procedures were taken into account when preparing the post-test (achievement) First, using the current curriculum (Lebanese) as a guide, teaching objectives were established for the topics targeted in the class. To ascertain which strategy was more effective, their outcomes would be contrasted with those of the control group, which was instructed using traditional lecture-based strategy.

The posttest duration was 45 minutes, and it was made up from two exercises.

### 3.7 Validity of the post-test

Before any pre- or post-test is considered as a trustworthy instrument for gathering data, it must be validated. (TECH, 2007)

Chemistry coordinator and two teachers confirmed the validity of the instruments (curricular specialists approved). They looked over the tests and explained the questions, including whether they were testing and what they were supposed to test, they highlighted some changes

that led to a few slight modifications and remarks. They also made sure the items were clear to prevent ambiguity. They verified that the questions were suitable for the students in the study. They looked for any potential errors in the instrument and recommended fixes. Additionally, enough time was provided for answering the instrumental tests.

## Chapter IV: Result and Discussion

This chapter presents the findings of the study, which aimed to investigate the impact of using Phet simulations in teaching stoichiometry on Grade 10 students' learning outcomes. Descriptive statistics, tests of normality, paired sample t-tests, and Mann-Whitney U tests were employed to assess students' performance across control and experimental groups before and after the intervention.

### 4.1 Test of Normality

To determine the appropriate statistical tests, the normality of students' grade tests (Kolmogorov-Smirnov and Shapiro-Wilk) were performed for both the control and experimental groups to examine whether the data met the assumption of normality.

**Table 1:**

**Tests of Normality (Shapiro-Wilk) for students' Grades**

| Group | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Control Group | 0.148 | 20 | .200* | 0.956 | 20 | 0.459 |
| Experimental Group | 0.151 | 39 | 0.026 | 0.928 | 39 | 0.016 |

The Shapiro-Wilk test showed that the control group's data was normally distributed (W = 0.956, p = .459). However, the experimental group data significantly deviated from normality (W = 0.928, p = .016), justifying the use of non-parametric tests for inter-group comparisons involving the experimental group.

### 4.2 Findings from Pre and Post-tests

This section presents the changes in student performance within and between groups based on pre-test (Term 1 average grades) and post-test scores.

#### 4.2.1 Homogeneity of the groups before the intervention

To examine the homogeneity of the groups before the intervention, the Term 1 average grades were analysed (Table 2). The control group (Class A) had a mean of 12.73 (SD = 3.48), while the combined experimental group (Classes B and C) had a mean of 12.55 (SD = 3.62). The difference between the groups was minimal (1.01%), suggesting that students had comparable academic levels before the treatment phase, thus supporting the validity of the comparative analysis conducted post-intervention.

**Table 2:**

**Baseline Comparison of Student Performance**

| | Control Group | Experimental Group | | |
|---|---|---|---|---|
| | Class A | Class B | Class C | Class A & B |
| N | 20 | 19 | 20 | 39 |
| Mean | 12.73 | 12.66 | 12.45 | 12.55 |
| Std. Deviation | 3.48 | 3.77 | 3.56 | 3.62 |

### 1.1.2 Control Group

Analyses of the intra-group test results for the control group were performed using paired samples tests to compare performance before (pre-test) and after (post-test) the intervention. The results are presented in the tables below.

**Table 3:**

**Descriptive Statistics for Pre- and Post-Test Scores in the Control Group**

| Test Type | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Pretest | Section A (CG) | 20 | 12.73 | 3.48 |
| Posttest | Section A (CG) | 20 | 13.40 | 3.61 |

The control group showed a slight improvement in performance from pre-test (M = 12.73, SD = 3.48) to post-test (M = 13.40, SD = 3.61).

**Table 4:**

**Paired Sample T-Test for Control Group**

| **Paired Samples Correlations** | | | | |
|---|---|---|---|---|
| | | N | Correlation | Sig. |
| Pair 1 | Mean Pretest Control Group (Section A) & Mean Posttest Control Group (Section A) | 20 | 0.998 | 0.000 |

| **Paired Samples Test** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired Differences | | | | | | | |
| | | | | 95% Confidence Interval of the Difference | | | | | |
| Mean | | Std. Deviation | Std. Error Mean | Lower | Upper | | t | df | Sig. (2-tailed) |
| Pair 1 | Mean Pretest Control Group (Section A) - Mean Posttest Control Group (Section A) | −0.67500 | 0.24468 | 0.05471 | −0.78951 | −0.56049 | −12.337 | 19 | 0.000 |

The paired-sample t-test revealed a statistically significant improvement, $t(19) = -12.34$, $p < .001$, indicating a modest yet significant learning gain through traditional instruction. The effect size, Cohen's $d = 2.76$, indicates a very large impact of the traditional method.

### 4.2.3 Experimental Group

Analyses of the intra-group test results for the experimental group were performed using Mann-Whitney U tests to compare performance before (pre-test) and after (post-test) the intervention. The results are presented in the tables below.

**Table 5:**

**Experimental Group Pre and Post-test Scores**

| Grades Report | | | | | | |
|---|---|---|---|---|---|---|
| | Section B (EG1) (N=19) | | Section B (EG2) (N=20) | | All Sections (N=39) | |
| Pretest | M=12.66 | SD=3.77 | M=12.45 | SD=3.56 | M=12.55 | SD=3.62 |
| Posttest | M=15.39 | SD=2.83 | M=15.53 | SD=2.67 | M=15.46 | SD=2.71 |

Both experimental sections (B and C) showed improvement, with combined post-test scores averaging M = 15.46 (SD = 2.71), compared to pre-test scores M = 12.55 (SD = 3.62).

**Table 6:**

**Mann-Whitney U Test for Experimental Group Pre- and Post-Test Comparisons**

| Descriptive Statistics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Percentiles | | |
| | N | Mean | Std. Deviation | Minimum | Maximum | 25th | 50th (Median) | 75th |
| Grades | 78 | 14.01 | 3.50 | 7.00 | 20.00 | 11.50 | 14.00 | 17.00 |
| Test Type | 78 | 1.50 | 0.503 | 1 | 2 | 1.00 | 1.50 | 2.00 |

**Mann-Whitney Test**

**Ranks**

| Test Type | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Grades | Pretest | 39 | 30.35 | 1183.50 |
| | Posttest | 39 | 48.65 | 1897.50 |
| | Total | 78 | | |

**Test Statistics[a]**

| | Grades |
|---|---|
| Mann-Whitney U | 403.500 |
| Wilcoxon W | 1183.500 |
| Z | -3.575 |
| Asymp. Sig. (2-tailed) | 0.000 |

a. Grouping Variable: Test Type

The Mann–Whitney U test indicated a statistically significant improvement in the experimental group, U = 403.5, Z = −3.575, $p < .001$.

### 4.2.4 Comparison between the control and the experimental groups Post–test results

The descriptive statistics of the variables measured in the post–tests for both groups (control group and experimental group) as well as the analysis of the intra–group test results for both groups performed using Mann–Whitney U tests to compare their performance after the intervention (post–test). The results are presented in the tables below:

**Table 7:**

**Descriptive Statistics for Post–Test Scores Across Groups**

| **Post–Tests Grades Report** | | | | |
|---|---|---|---|---|
| | **Control Group** | **Experimental Group** | | |
| | Class A | Class B | Class C | **Class B & C** |
| N | **20** | 19 | 20 | **39** |
| Mean | **13.40** | 15.39 | 15.53 | **15.46** |
| Std. Deviation | **3.61** | 2.83 | 2.67 | **2.71** |

The experimental group scored significantly higher (M = 15.46, SD = 2.71) than the control group (M = 13.40, SD = 3.61) in the post–test.

**Table 8:**

**Mann-Whitney U Test Comparing Post-Test Scores Between Groups**

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum | Percentiles 25th | 50th (Median) | 75th |
|---|---|---|---|---|---|---|---|---|
| Grades | 59 | 14.76 | 3.17 | 7.00 | 19.50 | 12.5000 | 15.0000 | 18.0000 |
| Group | 59 | 1.66 | 0.48 | 1 | 2 | 1.00 | 2.00 | 2.00 |

**Mann-Whitney Test**

**Ranks**

| Group | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Grades | Control Group | 20 | 23.08 | 461.50 |
| | Experimental Group | 39 | 33.55 | 1308.50 |

**Test Statistics[a]**

| | Grades |
|---|---|
| Mann-Whitney U | 251.500 |
| Wilcoxon W | 461.500 |
| Z | -2.223 |
| Asymp. Sig. (2-tailed) | 0.026 |

a. Grouping Variable: Group

Results revealed a statistically significant difference in post-test scores favouring the experimental group, U = 251.5, Z = -2.223, p = .026. The effect size (r = 0.29) suggests a small to medium educational impact.

Chapter V: Discussion and Conclusion

## 5.1 Discussion of the Findings

The study aimed to answer the research question: How does the use of Phet simulations in teaching stoichiometry impact grade 10 students' understanding and performance in chemistry compared to traditional teaching methods?

To address this, student performance was compared across three groups: a control group taught using traditional methods and two experimental groups taught using Phet simulations.

The results showed a statistically significant difference in performance between the groups:

The experimental group showed greater improvement in post-test scores ($M = 15.46$, $SD = 2.71$) compared to the control group ($M = 13.40$, $SD = 3.61$).

A Mann-Whitney U test confirmed this difference was statistically significant ($U = 251.5$, $p = .026$).

Additionally, within-group comparisons revealed that the experimental group had significant learning gains from pre-test to post-test ($Z = -3.575$, $p < .001$), while the control group also improved, but to a lesser extent ($t(19) = -12.337$, $p < .001$).

These findings confirm that simulation-based learning using Phet tools significantly enhances students' understanding of stoichiometry compared to traditional teaching approaches. The results support constructivist learning theory, which emphasizes interactive, student-centered learning environments that promote conceptual change and deeper understanding.

### 5.2 Validation of the Hypothesis

The hypothesis proposed that the use of simulation-based learning has a positive influence on student outcomes compared to traditional methods. The statistically significant improvement observed in the experimental group supports this hypothesis. Therefore, the findings affirm that Phet simulations enhance conceptual understanding and student performance in chemistry.

## 5.3 Implications for Practice

Educators are encouraged to integrate Phet simulations into their instructional practices, especially when teaching abstract scientific concepts. Training and support should be provided to ensure teachers can effectively use these tools to enrich the learning experience.

## 5.4 Limitations

The study was limited to a single school with a relatively small sample size. Moreover, the absence of a delayed post-test limits the assessment of long-term learning retention.

- **Sample Size and Generalizability:** Only 59 students from a single private school contributed to the study's relatively small sample size. This makes it more difficult to generalize the results. To improve the generalizability of the findings, future research should include a bigger sample size from a variety of educational settings or schools.
- **Single school:** Context of a Single School: The study was conducted in a single school, which might have limited the range of instructional concepts, student backgrounds, and technology resources.
- **Lack of Long-Term Follow-up:** A delayed post-test to evaluate long-term retention of stoichiometry concepts following the intervention was not included in the study.
- **Insufficient utilization of technology Tools:** Although Phet simulations are an excellent form of educational technology,

they are the sole focus of this study.

## 5.5 Recommendations for Future Research

Future research should include a larger and more diverse sample and assess long-term retention of concepts. Comparative studies between different educational technologies (e.g., Phet vs. AR) may also be valuable. A delayed post-test or follow-up research might also be used to evaluate how well stoichiometry ideas are retained over time and ascertain whether the gains made using Phet simulations were worthwhile. Finally, other studies might look into how well Phet simulations teach biology or physics, among other science courses. This would give a more thorough grasp of the various fields in which this technology can be used.

## 5.6 Conclusion

This study concludes that teaching stoichiometry using Phet simulations significantly improves student understanding and performance. Such technology-enhanced learning tools offer effective alternatives to traditional methods and should be adopted more widely in science education.

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