# A Comparison of Virtual Simulation and 3D Model as Tools in Teaching and Learning Rates of Reaction in Science 8

**Abigail V. Amil (MaEd Science), Dondon B. Buensuceso (Ph.D)**

**FEU Roosevelt, Cainta, Rizal, Philippines**

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## ABSTRACT

In the dynamic landscape of science education, this study pioneers an exploration into the transformative potential of virtual simulation and 3D models as instructional tools for elucidating rates of reaction in Grade 8 science classrooms. As the demand for innovative teaching methodologies escalates, understanding the nuanced impact of these technologies is paramount for educators seeking to optimize the learning experience. This research aimed to redefine the trajectory of science education by unveiling the untapped potential within virtual simulations and 3D models. The results are poised to equip educators, curriculum designers, and policymakers with insights to transform educational approaches, ushering in an era where technology seamlessly integrates with traditional teaching methods. This convergence aims to enhance the educational experience for every eighth-grade student. This study employed experimental research using pretest and posttest design and investigated the effectiveness and comparison of two instructional tools, virtual simulation and 3D models, in enhancing the teaching and learning of rates of reaction in eighth-grade science. Data from respondents were gathered through the implementation of pretest and posttest questionnaire methods. Subsequently, the results underwent detailed statistical analysis, including the computation of weighted mean, standard deviation, T-test, and Anova Test. The results indicated that, as assessed through T-tests, the scores of the two experimental groups significantly increased after the implementation of virtual simulation and 3D models. Nevertheless, the Anova test revealed that there was no statistically significant impact on the learning performance of Grade 8 students when comparing pretest and posttest scores before and after the interventions. Upon uncovering the study's outcomes, the researcher developed a training program plan aimed at improving students' proficiency in understanding rates of reaction. Simultaneously, the plan seeks to augment educators' knowledge by incorporating various instructional tools within science classrooms.

**Keywords:** Virtual Simulation, 3D models, Instructional Tools for Science, Enhancing Teaching-Learning, Teaching-Learning Rates of Reaction

## INTRODUCTION

The primary goal of education is to maximize each student's potential by delivering effective, multisensory instruction that encourages interactive learning. Globally, nations recognize that strong science and technology education is essential for national development, as no country can advance scientifically without a solid foundation in science education (Eddy, 2019). Science disciplines such as Physics, Chemistry, Mathematics, and Biology rely heavily on laboratory work to engage students actively, offering firsthand experiences that foster critical thinking through open-ended experiments where students test hypotheses and develop their own ideas (Hadzigeorgiou and Schulz, 2019). Recent educational transformations driven by technological progress have introduced various instructional media, including computer simulations, which have gained prominence as powerful pedagogical tools across fields like aviation and nursing, expanding opportunities for interactive, inclusive, and effective teaching (Rooney and Nyström, 2018). In science, 3D models further support learning and research by allowing scientists to simulate complex phenomena, visualize intricate data, and explore detailed structures, thereby enhancing understanding and facilitating innovation in diverse disciplines (Patel, 2021). Together, these advancements in technology and pedagogy are revolutionizing education and research, equipping learners and professionals to meet modern challenges confidently.

## Background of the Study

Thai-Singapore International School (TSIS) is among the distinguished educational institutions that follow the widely acclaimed International General Certificate of Secondary Education (IGCSE) curriculum, leading students to achieve Cambridge IGCSE qualifications that hold international recognition and value. In April 2023, a Checkpoint test was given to the Lower Secondary 2 (Grade 8) which includes Mathematics subject, English subject, and Science subject. According to the checkpoint test results for the Science subject, administered by Cambridge International, it was evident that the students gained an average of 28 and did not achieve the international passing average of 32. More precisely, the students exhibited low academic performance, particularly in Chemistry. Chemistry is widely recognized as a crucial scientific discipline essential for comprehending various natural phenomena, and it forms the foundation for the understanding of numerous other sciences. Despite its significance, numerous students worldwide encounter challenges in mastering chemistry, with a particular struggle often arising in understanding topics related to chemical reactions (Kajornklin, P, et al. 2022). Tamuang et al., (2018) highlighted the high school level poses various significant difficulties, challenges, and obstacles when it comes to teaching and learning chemistry. Firstly, a considerable number of students lack adequate hands-on experience in conducting chemistry experiments, which can impede their ability to fully grasp the practical aspects of the subject. Secondly, the reliance on traditional experiments often proves to be a limitation as it restricts students from exploring a diverse range of practical applications. Lastly, the conceptual understanding of chemistry can be particularly challenging for some students. By promoting hands-on experiences, encouraging exploration of practical applications, and employing effective teaching strategies to enhance conceptual understanding, educators can empower students to develop a strong foundation in chemistry and spark a lasting interest in the subject. The researcher aimed to address this concern about the low academic performance of students in checkpoint test in chemistry by attempting to enhance the learning process of the Grade 8 (Lower Secondary 2) students specially in rates of reaction, one of the topics the researcher taught in school year 2023-2024. In this study, the researcher utilized virtual simulation and 3D model in teaching rates of reaction.

## Science Teaching and Learning

Learning science involves developing conceptual knowledge, procedural skills, and ways to express understanding, all supported by scientific thinking such as logical analysis and critical evaluation (Zhang et al., 2022). Effective learning builds on prior knowledge and social interaction, with strategies like cooperative learning, hypothesis testing, and reflective questioning promoting deeper engagement and critical thinking (Lott and Clark, 2019; Bae et al., 2022). Skilled science teachers use high-level questioning to stimulate discussion, and providing ample response time encourages more thoughtful participation, especially from less confident students (Vlacholopoulos and Makri, 2018; Matute-Vallejo and Melero-Polo, 2019).

## Science Learning Activities

Science learning centers on three key activities: building conceptual knowledge through reading and observation, developing procedural skills via hands-on experiments, and expressing understanding through various responses or creative means. Scientific thinking, which involves questioning and logical reasoning beyond memorization, is essential to this process (Zhang et al., 2022). Educators enhance learning by using methods like cooperative learning, hypothesis testing, and visual aids to foster active engagement (Bae et al., 2022). Effective teachers employ thoughtful questioning that encourages reflection and explanation, and by allowing enough time for student responses, they promote deeper understanding and confidence, resulting in more meaningful discussions (Matute-Vallejo and Melero-Polo, 2019).

## Science Teaching Tools

A science teacher's main aim is to communicate effectively to achieve educational goals, ensuring students grasp and benefit from the material (Ordu, 2021). Science education emphasizes inquiry and exploration, with students gaining technological skills to tackle real-world global issues using tools like PhET Simulations and NASA's resources that blend content with interactive learning (Common Sense Education, 2023). Sudarto (2022) highlights the importance of humanistic scientific tools in nurturing intellectual, emotional, and creative growth, while Kapur (2020) stresses that selecting appropriate teaching aids is key to enhancing learning outcomes. Incorporating visuals, videos, and social media helps maintain student engagement by making complex concepts accessible and stimulating curiosity (Ordu, 2021).

**Traditional Lecture Method**

The lecture method, recognized as the oldest form of teaching, is a teacher-centered approach where the instructor plays a dominant role by delivering content primarily through verbal explanations, supported by body language, simple tools, voice modulation, movement, and facial expressions. Although this method makes the teacher more active and students relatively passive, teachers often pose questions to encourage interaction and maintain student focus. According to Oladejo (2022), this traditional strategy emphasizes teacher-led instruction with limited student participation. Okebukola et al. (2020) further explain that in such settings, students primarily listen while the teacher speaks without interruption, offering few chances for learners to ask or answer questions. Specifically in subjects like chemistry, this passive learning style—often involving "chalk and talk"—can lead students to view the subject as overly complex and reliant on memorization, which may hinder their interest and active engagement.

**3D Model (Laboratory Apparatus and Equipment)**

When direct access to scientific materials is limited, scientists and educators often rely on models to better understand their structure and function. These models—ranging from scaled versions to digital or physical constructs—help students grasp complex ideas by engaging them in activities like building, analyzing, and comparing models to real-world systems, such as constructing an atom model (Koch, 2018). Incorporating engineering design challenges into science education encourages active learning and supports understanding of abstract concepts. Laboratory experiences, meanwhile, remain essential for deepening students' understanding in subjects like biology, chemistry, and physics. Hands-on experiments with appropriate lab equipment and chemicals not only reinforce theoretical knowledge but also develop practical skills and problem-solving abilities (Restiana & Djukri, 2021). Models offer a tangible and visual representation of objects, helping students explore various dimensions and properties; examples include globes, anatomical figures, and geometric shapes, which can be examined from multiple angles and scales (Babalola et al., 2022; Rouse & Haughn, 2016; Byjus, 2020). Koch (2018) further emphasizes the importance of active student participation in scientific and technological practices, where experimentation and iterative design mirror real-world engineering processes. Familiarity with laboratory procedures and tools is crucial not only for skill development but also for translating classroom theories into practical understanding, equipping students with competencies needed for 21st-century learning (Restiana & Djukri, 2021).

**Advantages of 3D Model in Science Teaching-Learning**

Teplá et al. (2022) explain that the process of 3D modeling aligns with constructivist learning theories, as it involves a gradual, step-by-step construction of knowledge through assembling virtual components, which can later be physically realized using 3D printing. This hands-on engagement allows students to take an active role in learning by conceptualizing, designing, and creating, thus shifting them from passive recipients to active constructors of scientific understanding. Brau (2020) supports this approach through a historical perspective on constructivism, tracing its roots to Socrates 'belief in igniting the mind rather than filling it, further developed by Dewey, Vygotsky, and Piaget, who emphasized learning through active involvement, social interaction, and developmental stages. In educational settings, such as geography or geology, 3D models help students visualize and manipulate complex structures from multiple angles—experiences that traditional materials cannot offer. Through structured 3D visualization modules, students enhanced their spatial reasoning and applied their learning in problem-solving tasks, with measurable gains in comprehension. Loftin (2018) highlights further benefits of 3D models, including the ability to safely examine rare or delicate specimens, offer unlimited study time, enable global sharing of resources, and provide interactive and scalable learning tools. These models also support advanced analytical techniques like precise measurements and repeated testing, making them valuable assets in both education and research.

**Disadvantages of 3D Model in Science Teaching-Learning**

Scientific models are essential tools for representing and understanding complex natural phenomena, as they simplify and visualize objects, systems, or events that may be difficult to observe directly (Restiana & Djukri, 2021). They enable scientists to communicate ideas, grasp intricate processes, and make predictions. However, as Pujol et al. (2018) note, these models are simplifications and cannot encompass every detail—for instance, maps cannot display all Earth's physical features due to scale limitations, and atomic models like ball-and-stick diagrams omit many structural complexities. The Texas Education Agency (2023) further emphasizes that while 3D models can replicate the external form of objects, they often fail to capture tactile and material qualities essential for deeper understanding. These models may appear overly artificial, suffer from material degradation, and lack the detailed craftsmanship of originals. Moreover, producing high-fidelity 3D models can be costly and technically demanding, requiring specialized expertise and equipment. In essence, although scientific models greatly enhance comprehension and communication, their effectiveness is tempered by simplifications, material constraints, and practical limitations.

**Virtual Simulation**

Screen-based or virtual simulation games represent a highly interactive educational strategy that employs advanced computer technology to replicate real-life scenarios on a digital platform, offering learners an engaging and immersive environment for experiential learning and skill development. These simulations closely mirror authentic situations, allowing students to apply knowledge and problem-solving skills in a realistic yet safe setting, which fosters deeper understanding and meaningful learning outcomes. As Anderson et al. (2021) explain, virtual simulations involve participants taking on roles and engaging in decision-making, motor control, and communication within a screen-based environment, resulting in a partially immersive experience that often "feels very real." In healthcare education, this approach has become a widely accepted assessment tool, providing tailored clinical experiences that reflect real professional settings and patient interactions. According to Zackoff et al. (2021) and others, virtual simulations have proven effective in helping medical and nursing students, as well as practicing professionals, develop critical clinical competencies essential for their careers.

**Virtual Simulation in Science Teaching-Learning**

Interactive science simulations, or "sims," have become widely recognized as powerful tools for enhancing science education, with research showing their potential to significantly improve student performance and learning outcomes. PhET simulations, in particular, offer considerable versatility in classroom application, though new users may initially have questions about how best to incorporate them into their instruction (Price et al., 2019). A study by Perkins, Moore, and Chasteen involving over 1,500 high school teachers highlighted the varied methods and motivations for using PhET sims, emphasizing their role in promoting active student engagement and deeper understanding of scientific concepts. These simulations are especially valuable for aligning instruction with the Next Generation Science Standards (NGSS). Fogg et al. (2020) recommend a collaborative approach when integrating virtual simulations, beginning with a thorough needs assessment and determining how and where to best implement them. To be most effective, virtual simulation activities must clearly align with learning objectives, reflecting the core principle of adult learning, which stresses the importance of relevant and meaningful educational tasks. Educators, therefore, need to fully understand the purpose and educational value of these tools to use them successfully.

**Advantages of Virtual Simulation in Science Teaching-Learning**

Simulation tools offer significant advantages over traditional teaching methods by transforming abstract concepts into interactive, visual experiences that promote deeper understanding and skill development. According to Edubirdie (2023), simulations allow learners to interact with digital equipment, receive feedback, and practice procedures in a safe, cost-effective environment, minimizing risk to themselves and real-world systems. These tools can mimic various scenarios, including emergencies, making students better prepared for real-life applications. Jensen and Konradsen (2018) emphasize the educational benefits of head-mounted displays (HMDs), which enhance cognitive, affective, and psychomotor skills, especially through immersive experiences that support the development of spatial understanding and interpersonal competencies. Although psychomotor training through virtual tools may be more effective in higher education due to advanced device requirements, simulations are also useful in primary education by reinforcing cognitive learning (Sipilä, 2020). Jiang et al. (2019) note that virtual environments can replicate classrooms or labs, allowing teachers to create tailored learning experiences and monitor progress efficiently. These tools enable flexible, on-demand training, reducing dependency on physical equipment and boosting cost-efficiency in the long run (Desai, 2020). Yuan (2020) summarizes that simulations support the development of mental models, help students understand variable relationships and equations in real-world contexts, encourage collaboration, and make it possible to explore phenomena beyond the physical limits of classrooms or labs.

**Disadvantages of Virtual Simulation in Science Teaching-Learning**

Modern technology has become deeply embedded in daily life, with virtual simulation standing out as a particularly engaging innovation, especially among young people. While its immersive and entertaining nature draws attention, educators are increasingly considering its educational potential, prompting debate over its benefits and drawbacks (Edgar et al., 2022). Fransson et al. (2020) highlight that economic and technological barriers limit widespread adoption of virtual simulation in schools, as the high costs of hardware and software are often beyond the budgets of many educational institutions. Additionally, Jensen and Konradsen (2018) note a shortage of tailored educational content for virtual simulations, which are often designed more for individual learning than classroom use. Practical challenges also arise, such as managing limited devices in classrooms and exploring alternatives like smartphone-based simulations, which themselves raise equity concerns due to varying student access (Anderson et al., 2021; Fransson et al., 2020). Health-related issues like "cybersickness" and eye strain, especially for younger students, present further complications (Jensen & Konradsen, 2018). Moreover, cognitive overload from the rich, immersive environments can hinder learning outcomes (Fransson et al., 2020). While virtual simulation offers unique educational advantages, these must be balanced against challenges such as lack of authentic human interaction, limited content flexibility, potential technical malfunctions, risk of addiction, and high costs that contribute to unequal access among students (Edubirdie, 2023). These factors illustrate that despite its promise; virtual simulation requires thoughtful integration and ongoing resolution of barriers to become a practical and equitable educational tool.

**The Effectiveness of Virtual Simulation and 3D models in Science Teaching and Learning**

The National Science Teachers Association (NSTA) emphasizes that the successful integration of virtual simulations and e-learning into science education depends on their strategic and thoughtful incorporation into curricula from preK through higher education (Hansen et al., 2023). NSTA supports electronic experiential learning across diverse settings—traditional classrooms, informal environments, and online platforms—defining e-learning as the effective combination of virtual content with supportive resources to enhance science teaching and learning. E-learning, endorsed by the NRC, broadens access to science education through three-dimensional (3D) learning, accommodating diverse student needs while offering teachers opportunities to build confidence in technology use. Studies, such as Babalola et al. (2022), demonstrate that 3D models significantly improve student understanding—for instance, a 3D digestive system model acts as a cognitive bridge aiding comprehension. Similarly, Mar et al. (2021) and Patel et al. (2021) found that both 3D reconstructions and affordable handmade models effectively enhance anatomy education, especially where institutional resources are limited, improving students 'grasp of spatial relationships and anatomical variations (Pujol et al., 2018). E-learning's remote accessibility via digital devices allows students and teachers to engage in scientific inquiry beyond traditional constraints, fostering skills essential for the modern workforce. Hansen et al. (2023) outline key elements for quality e-learning: applying current learning research, purposeful design, alignment with standards, expert facilitation, personalized instruction, and collaborative real-world science experiences. Regular interaction between educators and students, continuous assessment, and program evaluation ensure ongoing improvement. In practice, many teachers use PhET simulations to promote inquiry-based learning and active student engagement (Price et al., 2019). Virtual simulations also inspire student motivation, as shown by Edgar et al. (2022) in optometry education, and positively influence intrinsic motivation in science subjects through dynamic visualizations, as revealed by Teplá et al. (2023). Given these findings, NSTA advocates integrating such digital tools broadly while preparing future educators to confidently employ technology, thereby enriching science education across all levels.

## The Theoretical Framework

### Experiential Learning Theory

Virtual simulation designers often base their work on theories like Kolb's Experiential Learning Model, which educators should understand to effectively integrate these interactive tools into teaching (Verkuyl et al., 2022).

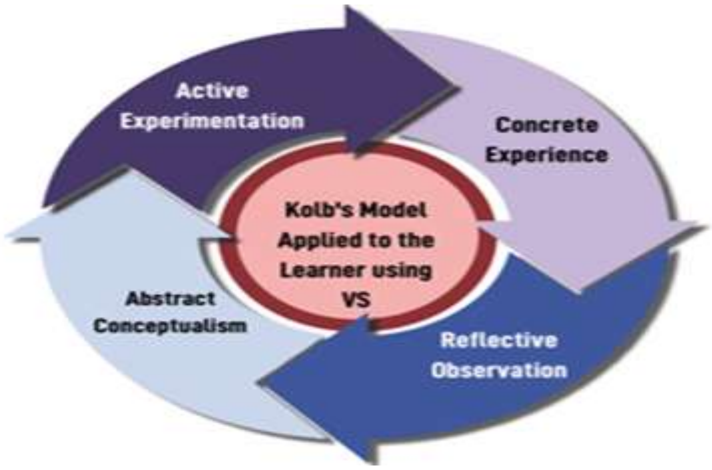


Figure 1– Kolb's Model Applied to Learners using Virtual Simulations

The figure depicts the ongoing, cyclical phases of learning in virtual simulation—active experimentation, concrete experience, reflective observation, and abstract conceptualization—highlighting that the process has no fixed start or end points (Verkuyl et al., 2022).


Figure 2– Kolb's Model Applied to Simulationist facilitating Virtual Simulations

The figure outlines the stages of virtual simulation facilitation—active experimentation, concrete experience, reflective observation, and abstract conceptualization—emphasizing the ongoing, cyclical nature of learning (Verkuyl et al., 2022). Based on Kolb's experiential learning theory, which highlights learning through new experiences applied in different contexts (Wangdi et al., 2020), Parno et al. (2021) showed that combining experiential STEM models with formative assessment boosts students 'understanding. Using virtual simulations alongside 3D models in teaching reaction rates engages students by allowing hands-on manipulation of chemical reactions and tactile exploration of molecular structures, fostering deeper comprehension by connecting theory to practice.

### Statement of the Problem

The study pointed to investigate A Comparison of Virtual Simulation and 3D Model as Tools in Teaching and Learning Rates of Reaction in Science 8. Specifically, it did the following:

1. What are the pre-test scores of the Grade 8 students in the control group and two experimental groups before Virtual Simulation and 3D model are used?

2. What are the post-test scores of the Grade 8 students in the control group and two experimental groups after Virtual Simulation and 3D model are used?

3. Is there a significant difference in the pre-test and posttest scores of the Grade 8 students in the control group and two experimental groups before and after Virtual Simulation and 3D model were used?

4. Is there a significant difference in the scores of the Grade 8 students that were assessed for effectiveness of using interventions?

   4.1 Pretest scores: Control Group Vs Virtual Simulation Vs 3D Model
   4.2 Posttest Scores: Control Group Vs Virtual Simulation Vs 3D Model

5. What training program can be proposed based on the findings of the study?

**Hypotheses**

1. There is no significant difference between the pretest and posttest scores of Grades 8 students in the control group and two experimental groups before and after using virtual simulation and 3D model.

2. There is no significant difference on the pretest and posttest scores of Grades 8 students in virtual simulation and 3D model.

## METHODOLOGY

**Research Design**

This quantitative study utilized a pretest-posttest design, a common quasi-experimental approach for evaluating the effectiveness of an intervention by comparing participants 'performance before and after its implementation. According to Stratton (2019), this design is among the simplest methods for testing causal hypotheses and assessing the impact of specific program elements against predetermined objectives. The research focused on Grade 8 students at Thai-Singapore International School (TSIS), aiming to evaluate the effectiveness of virtual simulations and 3D models in science education. Pretest and posttest assessments were conducted using validated test items from Cambridge Checkpoint past papers. Students' performance was categorized as excellent (A*), proficient (A–B), needs improvement (C–D), or unsatisfactory (E–G). The lesson plan adhered to the IGCSE curriculum using the school's standard format, and data analysis was conducted using an ANOVA test to determine the significance of the intervention's effects.

**Locale of the Study**

The study took place at Thai-Singapore International School (TSIS), located in Samut Prakan, Thailand, which offers education from nursery to senior high school. TSIS follows the Singapore Ministry of Education curriculum for early years and the internationally recognized Cambridge IGCSE curriculum for secondary students. This learner-centered, inquiry-based program emphasizes creativity, problem-solving, and critical thinking, effectively preparing students for further studies. After IGCSE, students advance to AS and A levels, selecting subjects aligned with their interests and future academic goals, particularly in Sciences, Social Sciences, and Mathematics. As noted, "Cambridge IGCSE promotes learner-centered and inquiry-based learning approaches," supporting academic development (Cambridge IGCSE, n.d.). Class sizes range from 20 to 25 students, and all classrooms comply with Thailand's Ministry of Education safety standards.

**Participants**

The study involved Grade 8 students (ages 13–15) at Thai-Singapore International School during the 2023–2024 school year, using purposive sampling to select 63 participants divided into three heterogeneous groups: one

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control group, one virtual simulation group, and one 3D model group, each with 21 students based on their Grade 7 academic performance. All groups took a pretest, received instruction (traditional, virtual simulation, or 3D model). The control group was taught through conventional lecture-style instruction, which reflects the typical approach used in the school's standard science teaching. This method consisted of teacher-directed lessons, reliance on textbooks, and traditional board work without the incorporation of modern teaching aids or enrichment strategies. No supplementary tools such as multimedia resources or activities linking literacy and numeracy were applied. This group served as a reference point, enabling a fair assessment of the innovative teaching techniques implemented in the experimental groups. All groups completed a posttest to evaluate learning outcomes.

**Research Instruments**

To compare the effectiveness of virtual simulations and 3D models in teaching rates of reaction in Grade 8 science, the researcher used pretests, posttests, and lesson plans. The tests, each with 10 items, were based on the structure of Cambridge assessments and sourced from validated Cambridge Checkpoint past papers, which are free for Cambridge Curriculum Schools. The lesson plans followed the IGCSE curriculum and were created using the school's standard template.

**Selection of the Content and Teaching Tools**

The study centered on the topic of rates of reaction, as outlined in the IGCSE curriculum, covering factors such as temperature, surface area, concentration, catalysts, reversible and irreversible reactions, chemical equilibrium, and energy changes. This content was chosen due to student difficulties in grasping concepts related to reaction rates and equilibrium (Gegios et al., 2018). To address these challenges, the virtual simulation group used Gizmos ExploreLearning software, selected for its alignment with the curriculum and student level. The Gizmos ExploreLearning, an interactive platform offering standards-aligned science simulations. The "Rate of Reaction" simulation enabled learners to adjust variables like concentration, temperature, surface area, and catalysts in real time, providing immediate visual feedback through animated particle collisions and real-time graphs. This engaging tool, chosen for its curriculum relevance and suitability for the learners 'level, offered an effective virtual alternative to traditional labs, enhancing understanding of chemical kinetics. While the 3D model group used physical models based on standard IGCSE lab setups. The rates of reaction laboratory set up used real chemicals and common lab equipment like beakers, measuring cylinders, stirring rods, and heat sources for hands-on experiments. Students manipulated factors such as concentration, temperature, surface area, and catalysts to observe their effects on reaction speed, noting changes like color shifts and gas production. With precise timing and measurement tools, this practical approach helped students connect theoretical concepts to real-world chemical behavior through direct observation and experimentation.

**Data Gathering Procedure**

The researcher administered a pretest to assess students 'prior knowledge before using virtual simulation and 3D models and created PowerPoint slides to support the lesson. Each group received 2 hours of instruction—experimental groups spent the first hour learning the lesson and how to use the tools, and the second hour applying them. A posttest followed to measure the effectiveness of these tools, and recommendations were made based on the results.

**RESULTS**

Table 1 Scores of Grade 8 Students Before the Interventions in the Control Group and Experimental Groups

| Score Interval | Description | Control Group | | Experimental Group (Virtual Simulation) | | Experimental Group (3D Model) | |
|---|---|---|---|---|---|---|---|
| | | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| 1 – 3 | Poor | 1 | 5 | 4 | 19 | 7 | 33 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 – 6 | Average | 11 | 52 | 12 | 57 | 9 | 43 |
| 7 – 8 | Good | 5 | 24 | 3 | 14 | 5 | 24 |
| 9 – 10 | Excellent | 4 | 19 | 2 | 10 | | |
| Total | | 21 | 100 | 21 | 100 | 21 | 100 |
| Mean | | **6.29** | | **5.19** | | **4.48** | |
| SD | | **1.82** | | **1.89** | | **1.94** | |

Table 2 Scores of Grade 8 Students After the Interventions in the Control Group and Experimental Groups

| Score Interval | Description | Control Group | | Experimental Group (Virtual Simulation) | | Experimental Group (3D Model) | |
|---|---|---|---|---|---|---|---|
| | | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| 1 – 3 | Poor | 2 | 10 | | | 1 | 5 |
| 4 – 6 | Average | 10 | 48 | 7 | 33 | 11 | 52 |
| 7 – 8 | Good | 5 | 24 | 10 | 48 | 7 | 33 |
| 9 – 10 | Excellent | 4 | 19 | 4 | 19 | 2 | 10 |
| Total | | 21 | 100 | 21 | 100 | 21 | 100 |
| Mean | | **7.10** | | **6.95** | | **6.00** | |
| SD | | **1.82** | | **1.89** | | **1.94** | |

Table 3 Difference in the Scores of the Grade 8 Students Before and After the Interventions

| Test | Test | Increase (Percent) | Computed Paired-T-test Value | p-value | Decision | Interpretation |
|---|---|---|---|---|---|---|
| Control Group | | | | | | |
| Pre-test | 6.29 | 0.81(13%) | -1.299 | 0.209 | Do not Reject the Null Hypothesis | Not Significant |
| Posttest | 7.10 | | | | | |
| Experimental Group – Virtual Simulation | | | | | | |
| Pre-test | 5.19 | 1.76(34%) | -5.017 | 0.001 | Reject the Null Hypothesis | Significant |
| Posttest | 6.95 | | | | | |
| Experimental Group | | | | | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| – 3D Model | | | | | | |
| Pre-test | 4.48 | 1.52(34%) | -4.128 | 0.002 | Reject the Null Hypothesis | Significant |
| Posttest | 6.00 | | | | | |

Note: p-value ≤ 0.05 – significant, p-value > 0.05 – not significant

Table 4.1 Difference in the Scores of the Grade 8 Students Before the Interventions in the Control Group and Experimental Groups

| Test | Mean | Computed ANOVA Value | p-value | Decision | Interpretation |
|---|---|---|---|---|---|
| Control Group | 6.29 | 4.919 | 0.011 | Reject the Null Hypothesis | Significant |
| Experimental Group – Virtual Simulation | 5.19 | | | | |
| Experimental Group – 3D Model | 4.48 | | | | |

Note: p-value ≤ 0.05 – significant, p-value > 0.05 – not significant

Table 4.1.1 Post Hoc Analysis in the Scores of the Grade 8 Students Before the Interventions in the Control Group and Experimental Groups

| Comparison | Mean Difference | p-value | Interpretation |
|---|---|---|---|
| Control Group vs Virtual simulation | 1.095 | 0.178 | Not Significant |
| Control Group vs 3D Model | 1.810 | 0.011 | Significant |
| Virtual Simulation vs 3D Model | 0.714 | 0.474 | Not Significant |

Table 4.2 Difference in the Scores of the Grade 8 Students After the Interventions in the Control Group and Experimental Groups

| Test | Mean | Computed ANOVA Value | p-value | Decision | Interpretation |
|---|---|---|---|---|---|
| Control Group | 7.10 | 2.099 | 0.131 | Do not Reject the Null Hypothesis | Not Significant |
| Experimental Group – Virtual Simulation | 6.95 | | | | |
| Experimental Group – 3D Model | 6.00 | | | | |

Note: p-value ≤ 0.05 – significant, p-value > 0.05 – not significant

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Table 5 TRAINING PROGRAM PLAN in enhancing scientific education especially mastering science teaching tools in science classroom

| **I. GENERAL PROGRAM INFORMATION:** | |
|---|---|
| **Program Title** | **"Enhancing Scientific Education: Mastering Teaching Tools for Dynamic Classroom Engagement"** |
| **Duration** | 2 Days |
| **Participants** | 20 Science Teachers |
| **Date** | January 4-5, 2024 |
| **Venue** | Thai-Singapore International School Conference Room 1 |
| **Delivery Mode** | Formal Face to Face |
| **Rationale** | In an era marked by swift technological progress, traditional methods of scientific education are primed for transformation. "Enhancing Scientific Education: Mastering Teaching Tools for Dynamic Classroom Engagement" stems from the acknowledgment that integrating innovative teaching tools is not merely a contemporary necessity but a revolutionary catalyst in the field of education. This initiative aims to bridge the widening gap between conventional teaching techniques and the ever-evolving learning preferences of today's students. By empowering educators to adeptly navigate an array of teaching tools—ranging from virtual labs and simulations to multimedia resources—this program endeavors to redefine the science classroom. It aspires to cultivate an environment where curiosity is ignited, critical thinking is nurtured, and scientific exploration evolves into an immersive and exhilarating journey.<br><br>The rationale behind this endeavor is firmly rooted in the conviction that education must be a dynamic and responsive undertaking. Scientific literacy transcends the mere conveyance of information; it hinges on instilling a sincere enthusiasm for exploration. Through this program, our goal is to furnish educators with the skills to leverage the potential of technology, ensuring that science education not only remains pertinent but also captivates the imagination. By mastering these teaching tools, educators can tailor their methods to suit diverse learning styles, involve students in hands-on experiences, and ultimately, inspire a new generation of scientists and innovators poised to confront the challenges of the future. |
| **Objectives** | By the end of the training program, the educators are able to:<br>1. demonstrate proficiency in utilizing at least three distinct teaching tools relevant to their science curriculum, showcasing their ability to navigate, integrate, and effectively apply these tools in classroom settings,<br>2. develop and present a sample interactive lesson plan incorporating a chosen teaching tool.<br>3. collaboratively design a learning module that integrates teaching tools to promote collaborative learning among students. |

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| | |
|---|---|
| **End of Program Outputs** | A. Formal Face to Face<br>At the end of the Training, the participants will present their outputs:<br>- Interactive lesson Plan incorporating a chosen teaching tool and<br>- Learning Modules that integrates teaching.<br><br>B. Expected Final Outputs<br>- Guided teachers to have proficiency in utilizing teaching tools.<br>- Knowledgeable and competent science teachers in using interactive teaching tools. |

**II. PROGRAM CONTENT FOCUS:**

| **Modules** | **Session Title** | **Session Objectives** | **Content** | **Duration** | **Expected Output** |
|---|---|---|---|---|---|
| 1 | Tool Proficiency<br>(Specially 3D model – Laboratory Apparatus) | demonstrate proficiency in utilizing at least three distinct teaching tools relevant to their science curriculum, showcasing their ability to navigate, integrate, and effectively apply these tools in classroom settings | 1.1 Introduction to Teaching Tools<br>1.2 Hands-on Tool Navigation<br>1.3 Integration Strategies | 1 hr and 45 minutes | |
| 2 | Interactive Lesson Design<br>(Specially<br>Virtual Simulation) | develop and present a sample interactive lesson plan incorporating a chosen teaching tool | 2.1Effective Lesson Planning<br>2.2 Tool-Specific Lesson Development<br>2.3 Interactive Presentation Skills | 2 hours and 30 minutes | Interactive Lesson Plans |
| 3 | | collaboratively design a learning module that integrates teaching | 3.1 Understanding Collaborative | 3 hours to 4 hours | Lesson Modules |

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| | | | | | |
|---|---|---|---|---|---|
| | Collaborative Learning Module | tools to promote collaborative learning among students | Learning<br>3.2 Module Design Workshop<br>3.3 Implementation Strategies | | |

**III. PROGRAM SCHEDULE:**

**Seminar Training Workshop on "Enhancing Scientific Education: Mastering Teaching Tools for Dynamic Classroom Engagement"**

January 4-5, 2024

Thai-Singapore International School, Conference Room 1

**I. Opening Program**

Opening Remarks

Statement of Purpose

**II. Seminar Proper**

**Tool Proficiency**

**Interactive Lesson Design**

**Collaborative Learning Module**

**III. Closing Ceremonies and Giving of Certificates**

Distribution of Certificates

**IV. Closing Remarks**

**IV. INTEGRATION SESSIONS:**

Throughout the training program, integration sessions will be conducted to ensure a holistic understanding of how educators can seamlessly combine the skills acquired from each module. These sessions will involve practical demonstrations, peer collaboration, and feedback loops to reinforce the application of teaching tools in diverse educational scenarios.

**V. ASSESSMENT AND REFLECTION:**

The program will conclude with assessments, where educators will showcase their proficiency in utilizing teaching tools, present their interactive lesson plans, and demonstrate the collaborative learning module. Reflection sessions will provide opportunities for feedback, self-assessment, and discussions on the practical implementation of the acquired skills in real-world classroom contexts.

## DISCUSSION

**Problem 1. Pre-test scores of the Grade 8 students in the control group and two experimental groups before Virtual Simulation and 3D model.**

Table 1 presents the pretest results of Grade 8 students across one control and two experimental groups before using virtual simulation and 3D models. In the control group, 5% (1/21) scored 1–3, 52% (11/21) scored 4–6, 24% (5/21) scored 7–8, and 19% (4/21) scored 9–10, with a mean of 6.29 and a standard deviation of 1.82. In the virtual simulation group, 19% (4/21) scored 1–3, 57% (12/21) scored 4–6, 14% (3/21) scored 7–8, and 10% (2/21) scored 9–10, with a mean of 5.19 and a standard deviation of 1.89. In the 3D model group, 33% (7/21) scored 1–3, 43% (9/21) scored 4–6, and 24% (5/21) scored 9–10, with a mean of 4.48. These results suggest that the control group began with a stronger understanding of the topic, indicating differing levels of prior knowledge among the groups. As noted, "all groups started at different level of intelligence or background knowledge."

**Problem 2. Post-test scores of the Grade 8 students in the control group and two experimental groups after Virtual Simulation and 3D model.**

Table 2 shows the posttest scores of Grade 8 students in the control group and two experimental groups after using virtual simulation and 3D models. In the control group, 10% (2/21) scored 1–3, 48% (10/21) scored 4–6, 24% (4/21) scored 7–8, and 19% (4/21) scored 9–10, with a mean of 7.10 and a standard deviation of 1.82. The virtual simulation group had 33% (7/21) scoring 4–6, 48% (10/21) scoring 7–8, and 19% (4/21) scoring 9–10, with a mean of 6.95 and standard deviation of 1.89. The 3D model group showed 5% (1/21) scoring 1–3, 52% (11/21) scoring 4–6, 33% (7/21) scoring 7–8, and 10% (2/21) scoring 9–10, with a mean of 6.00 and a standard deviation of 1.94. This suggests that while all groups improved, the control group maintained higher knowledge levels both before and after instruction, indicating that "all groups commenced and concluded the learning experience with varying levels of intelligence or background knowledge."

**Problem 3. Difference in the pre-test and posttest scores of the Grade 8 students in the control group and two experimental groups before and after Virtual Simulation and 3D model.**

The results in Table 3 indicate that both the virtual simulation and 3D model experimental groups showed a significant 34% improvement in pretest and posttest scores ($p = 0.001$), demonstrating their equal effectiveness in enhancing Grade 8 students' understanding of rates of reaction compared to the control group, which showed no significant change (13% increase, $p = 0.209$). These findings align with Celik (2022), who highlights that computer simulations foster active engagement and science process skills through experiential learning cycles, and Tepla et al. (2023), who emphasize the positive impact of 3D models and virtual tools on student learning. Moreover, Gurung and R (2023) and Suleman et al. (2019) support the integration of laboratory and virtual reality simulations as valuable methods to boost academic achievement and student motivation. El-Sabagh (2018) also found that virtual lab simulations combined with interactive activities and 3D animations significantly enhance conceptual understanding and science skills, confirming that both interventions are effective alternatives to traditional teaching methods for improving students 'learning outcomes in chemical kinetics. Overall, the data suggests that virtual simulation and 3D models are equally effective and valuable tools for teaching rates of reaction, enhancing student performance beyond traditional lectures.

**Problem 4.1 Difference in the pretest and posttest scores of the Grade 8 students before and after interventions were used**

The ANOVA results in Table 4.1 reveal a significant difference in the pre-test scores among the control and experimental groups ($F = 4.919$, $p = 0.011$), leading to the rejection of the null hypothesis and indicating that prior knowledge of rates of reaction varied among the students. Osman and Ratamun (2018) similarly found that virtual simulation labs did not outperform physical labs in enhancing students 'science process skills, although both approaches supported student-centered learning. Chan et al. (2021) reported that virtual chemical laboratory simulations had limited effectiveness in improving learning outcomes and student engagement compared to hands-on labs, while Pareek (2019) highlighted the inadequate implementation of both virtual and physical labs in many schools, which may contribute to inconsistent science performance. These findings suggest that the initial differences in students 'baseline knowledge could have influenced the results, with Post Hoc analysis further exploring the specific sources of these significant differences.

**Problem 4.1.1 Post Hoc Analysis in the Scores of the Grade 8 Students Before the Interventions in the Control Group and Experimental Groups**

The post hoc analysis in Table 4.1.1 indicates that there was no significant difference between the control group and virtual simulation group pre-test scores (mean difference = 1.095, $p = 0.178$), nor between the virtual simulation and 3D model groups (mean difference = 0.714, p = 0.474). However, a significant difference was found between the control group and the 3D model group (mean difference = 1.810, p = 0.011), suggesting that students in the 3D model group had prior experience with this type of laboratory setup. This aligns with findings by Osman and Ratamun (2018), who emphasized the impact of previous hands-on exposure on science process skills, while Celik (2022) noted that familiarity with learning tools influences student outcomes. These baseline differences among the groups likely contributed to the variation in pre-test scores and should be considered when interpreting the effectiveness of the interventions.

**Problem 4.2 Control Group vs Virtual simulation vs 3D model**

The posttest results in Table 4.2 show a decrease in the ANOVA value from 4.919 to 2.099 with a p-value of 0.131, indicating no significant difference in learning performance among the control and experimental groups after the use of virtual simulation and 3D models, thus failing to reject the null hypothesis. This aligns with findings by Penn and Ramnarain (2019), who noted that virtual labs complement physical labs effectively when addressing complex chemistry concepts. Similarly, Cruz et al. (2022) reported comparable academic outcomes between students using virtual simulators and traditional laboratory setups, highlighting students 'positive attitudes towards both approaches. Ayoubi and Faour (2018) also found equivalent conceptual gains from virtual simulations and interactive real-lab demonstrations, suggesting that both methods equally support student understanding, while raising the possibility that factors such as teacher effectiveness may further influence learning outcomes with these interventions.

**Problem 5. The training Program Plan in enhancing scientific education especially mastering science teaching tools in science classroom.**

The proposed training program is designed to improve the teaching and learning of science. It focuses on helping students better understand scientific concepts. Special emphasis is placed on enhancing performance in the topic of rates of reaction. Overall, the program aims to support both teachers and students in achieving better learning outcomes.

## SUMMARY OF FINDINGS

This paper sought to provide information on A Comparison Of Virtual Simulation And 3d Model As Tools In Teaching and Learning Rates of Reaction In Science 8.

Among the important findings of this research were:

1. The Pretest scores of Grade 8 students in the control group and two experimental groups before virtual simulation and 3D model was used.

   Before the interventions, the scores in the control group and two experimental groups were comparable: 33% of the students in the 3D model group received 1-3 scores the highest, while 5% of the students in the control group the lowest. 57% of the students in the virtual simulation group received 4-6 scores the highest, while 43% of the students in the 3D model group the lowest. 24% of the students in 3D model and control groups received 7-8 scores the highest, while 14% of the students in the virtual simulation group the lowest. 19% of the students in the control group received 9-10 scores the highest, while 0% in the 3D model group the lowest.

2. The Posttest Scores of the Grade 8 students in the control group and two experimental groups after virtual simulation and 3D model was used.

   After the interventions, the scores in the control group and two experimental groups were comparable: 10% of the students in the control group received 1-3 scores the highest, while 0% of the students in the virtual simulation group the lowest. 52% of the students in the 3D model group received 4-6 scores the highest, while 33% of the students in the virtual simulation group the lowest. 48% of the students in the virtual simulation group received 7-8 scores the highest, while 24% of the students in the control group the lowest. 19% of the students in the virtual group and control group received 9-10 scores the highest, while 10% of the students in 3D model group the lowest.

3. The significant difference in the pre-test and posttest scores of the Grade 8 students in the control group and two experimental groups before and after the virtual simulation and 3D model were used.

   The data revealed that the two experimental groups both increase of 34% before and after the implementation of virtual simulation and 3D model. As a result, it rejects the null hypothesis, highlighting the significant difference of both groups. On the other hand, it can be gleaned that there is no significant difference in control group since it has 13% increase in the scores of the students with p-value that is greater than 0.05 which is 0.209, hence, it accepts the null hypothesis.

4. The significant difference among 3 groups before and after interventions were used.

   4.1 Pretest scores of control group vs virtual simulation vs 3D model before the interventions

   There is significant difference in the scores of the students before the interventions were used and also, it showed significant results in the post hoc analysis emphasizing the control group vs 3D model.

   4.1 Posttest scores of control group vs virtual simulation vs 3D model after the interventions

   There is no significant difference in the scores of students after interventions were used, agreeing the post hoc analysis results in the pretest scores of the students.

   While ANOVA shows no significant difference in overall learning performance between the control and experimental groups ($p = 0.131$), paired t-tests reveal that both experimental groups significantly improved their scores by 34% after the interventions ($p = 0.001$). This difference exists because ANOVA compares performance across groups at one time point, while t-tests measure changes within each group over time. Understanding this distinction between within-group improvements and between-group comparisons clarifies that although both interventions boosted learning individually, their effects were not significantly different when groups were compared directly.

5. The proposed training program design plan to enhance teaching and learning science

   The training program plan designed to enhance the student's performance in learning science especially learning rates of reaction.

# CONCLUSIONS

Based on the foregoing findings, the following conclusions were drawn:

1. The two experimental groups' scores of Grades 8 students had lower means before interventions were implemented while the control group had the highest mean scores. It suggests that students in control group have a higher knowledge about the topic even before it was taught by the teacher. It only suggests that all groups started at different level of intelligence or background knowledge.

2. The two experimental groups' scores of Grades 8 students had lower means after using virtual simulation and 3D model compared in control group had a higher mean score. It implies that students in the control group exhibit elevated knowledge of the topic even after teacher instruction. This indication underscores the notion that all groups commenced and concluded the learning experience with varying levels of intelligence or background knowledge.

3. A significant difference on the two experimental groups before and after the implementation of the interventions: both groups' scores increased before after the implementation of virtual simulation and 3D model, hence the null hypothesis is rejected. Only the control group was not significant and rejected the null hypothesis. The data implies that both virtual simulation and 3D models have equal effect in contrast

to traditional lecture method of teaching and learning and are effective tools to increase the performance level of Grade 8 students in learning rates of reaction. Also, effective tools in teaching rates of reaction in the classroom.

4. The scores of students after using ANOVA test showed significant results before using interventions in the 3 groups. For this, post hoc analysis was followed to identify which group shows significant results, and it revealed that control group vs 3D model is significant. Control group vs virtual simulation is not significant, as well as virtual simulation vs 3D model. The results in all 3 heterogenous groups have a possible implication and one can be the baseline variable that some of the Grade 8 students are exposed in using 3D models in learning chemistry before the intervention was used and it might be the reason for the results. The scores of students in the posttest after interventions were used are subjected to ANOVA testing showed that there is no significant difference between the scores of students in the 3 groups. Following the pretest results which was significant and in the post hoc analysis. Therefore, it accepts the null hypothesis and concluded that there is no significant difference between 3 groups. Results imply that the interventions do not influence the scores of the Grade 8 students and their performance level in learning the rates of reaction.

   The results of the ANOVA test and the paired t-tests may initially appear conflicting, but this can be clarified by understanding the distinct analyses they represent. The ANOVA evaluates differences between the control and experimental groups' posttest scores and found no statistically significant difference ($p = 0.131$), indicating that no single group outperformed the others after the interventions. Conversely, the paired t-tests assess changes within each group from pretest to posttest, revealing significant improvements in the experimental groups (34% increase, $p = 0.001$). This means that while both the virtual simulation and 3D model interventions effectively enhanced student learning individually, their overall post-intervention performance did not differ significantly from one another or from the control group. The findings suggest that although the interventions promoted notable gains compared to each group's own baseline, the variation in learning outcomes across groups after treatment was not large enough to reach statistical significance. Recognizing the difference between within-group improvements and between-group comparisons provides a clearer interpretation of the data and highlights the value of both instructional methods in supporting student learning.

5. The training program plan designed to enhance the teachers' knowledge and proficiency in using scientific teaching tools for dynamic classroom management and to improve the performance of students in learning science.

## RECOMMENDATIONS

In the light of the conclusions drawn from the study, the following are hereby recommended:

1. Since using Virtual Simulation and 3D model do not have any difference, it is still recommended to use any of the teaching tools in enhancing the performance of students in teaching science as both teaching tools have same impact on students' performance.

2. Equitable Integration in Teaching Styles:

   Educators adopt teaching styles that ensure equitable integration of both virtual simulations, 3D models, and other technological teaching tools. Emphasize the importance of varied instructional methods to accommodate diverse learning preferences, allowing for a balanced and inclusive learning experience.

3. Comprehensive Training Programs and Continuous Professional Development:

   Advocate for comprehensive training programs for educators, focusing on the effective integration of virtual simulations and 3D models and other technological teaching tools into their teaching methodologies. Provide educators with the necessary skills to adapt their teaching styles, ensuring a seamless incorporation of these technological tools into the classroom. Encourage ongoing professional development for teachers to stay abreast of advancements in educational technology. This empower educators to continually refine their teaching styles and leverage emerging tools to enhance student learning experiences.

4. Diversified Lesson Planning:

   Advocate for educators to plan diverse lesson modules incorporating technological teaching tools. Encourage the creation of lesson plans that utilize both virtual simulations and 3D models, fostering a multifaceted approach that addresses varied learning styles and preferences.

5. Expanded Research Scope:

   Advocate for a broader exploration of technological teaching tools beyond virtual simulation and 3D models. Recommend conducting additional studies to encompass a wider array of emerging technologies, ensuring a comprehensive understanding of their potential impact on student performance. Also advocate for longitudinal studies to assess the sustained impact of virtual simulations and 3D models on student performance. Long-term research will provide valuable insights into the effectiveness of these tools in enhancing students' understanding and retention of scientific concepts. Also, the researcher needs to do the research using a new framework to an up-to-date one.

6. Comparative Studies Across Disciplines:

   Propose conducting comparative studies across different academic disciplines to understand the varying impacts of technological teaching tools. It shed light on subject-specific nuances and optimize the selection of tools tailored to diverse educational contexts. Also, the researcher needs to do the research using a new framework to an up to date one.

7. Consideration of Socioeconomic Factors:

   Highlight the need to consider socioeconomic factors that may affect access to technology both at home and in schools. Recommend strategies to bridge potential disparities to ensure that all students, regardless of their background, can benefit equally from the integration of virtual simulations and 3D models. Also, the researcher needs to do the research using a new framework to an up to date one.

8. School Policy Integration:

   The integration of policies at the school level that support and incentivize the effective use of virtual simulations and 3D models in teaching. This may include allocating resources, recognizing innovative teaching practices, and fostering a culture of technological integration. By implementing this, educational institutions can foster an environment that maximizes the benefits of both virtual simulations and 3D models, not only in terms of student performance but also in shaping dynamic and effective teaching practices.

## REFERENCES

1. Anderson, M., Lioce, L., M. Robertson, J., O. Lopreiato, J., & A. Díaz, D. (2021). Toward Defining Healthcare Simulation Escape Rooms. Simulation & Gaming, 52(1), 7–17. https://doi.org/10.1177/1046878120958745
2. Ayoubi, Zalpha & Faour, Malak Abou. (2018). The effect of using virtual laboratory on grade 10 students ’conceptual understanding and their attitudes towards physics. Journal of Education in Science, Environment and Health (JESEH), 4(1), 54-68. DOI:10.21891/jeseh.387482
3. B, Mar & Ch, Seye & K, Yacouba & Niang, Ibrahima & D, Seck & S, Sahoun & JM, Ndoye & Ndiaye, Assane & Niang, El & N, Diop & As, Ndiaye. (2021). 3D Digital Imagery a Solution for the Teaching of Osteology: Example of the Thoracic cage. International Journal of Anatomy and Research. 9. 8133-8138. 10.16965/ijar.2021.169.

4. Babalola, Ebenezer & Ekunola, Gbadebo & Omolafe, Eyiyemi. (2022). Effects of 3-Dimensional Model of Human Digestive System on Students Performance in Biology Concept in Nigeria. Journal of Digital Learning and Education. 2. 187-195. 10.52562/jdle.v2i3.431.
5. Bae et al. (2020). Engagement profiles of elementary students in urban settings
6. Bae et al. (2020). Opportunities to Participate (OtP) in science learning and student engagement: A mixed methods study. Journal of Educational Psychology
7. Bae et al. (2021) A systematic review of scientific discourse in urban K12 classrooms: Accounting for individual, collective, and contextual factors. Review of Educational Research
8. Bae et al. (2022). Hybrid Discourse Spaces: A Mixed Methods Study of Student Engagement in US Science Classrooms. Contemporary Educational Psychology
9. BrainKart. (n.d.). (2020). Three - Dimensional Aids: Models. BrainKart. Retrieved 1 July 2020, from http://www.brainkart.com/article/Three---Dimensional-Aids---Models_2200/.
10. Brau, B. (2020) Constructivism In R. Kimmons & S. Caskurlu (Eds.), The Students 'Guide to Learning Design and Research, EdTech Books.
11. BYJUS. (2020). Three Dimensional Shapes (3D Shapes)—Definition & Properties. BYJUS. https://byjus.com/maths/three-dimensional-shapes/
12. Çelik, B. (2022). The Effects of Computer Simulations on Students 'Science Process Skills: Literature Review.Canadian Journal of Educational and Social Studies,2(1), 16–28. https://doi.org/10.53103/cjess.v2i1.17
13. Chan, P., Van Gerven, T., Dubois, J.-L., & Bernaerts, K. (2021). Virtual chemical laboratories: A systematic literature review of research, technologies and instructional design. Computers and Education Open, 2, 100053. https://doi.org/10.1016/j.caeo.2021. 100053
14. Cruz, Urquizo E. P., Salcán, Sánchez N. de J., & Riofrío, Orrego M. C. (2022). Experimental Activities Using Virtual Simulators to Learn Chemistry During Covid-19 Pandemic. Chakiñan, Revista De Ciencias Sociales Y Humanidades, (17), 122–137. https://doi.org/10.37135/chk.002.17.08
15. Dakson A, Hong M, Clarke DB. (2018). Virtual reality surgical simulation: implications for resection of intracranial gliomas. Prog Neurol Surg. 2018; 30:106–16.
16. Desai, R. (2020). Digital learning (Digital Education). From http://drrajivdesaimd.com/2020/08/03/digital-learning-digital-education/
17. Eddy, S. L. (2019). Recent Research in Science Teaching and Learning. CBE- Life Sciences Education, 18(1), fe1. https://doi.org/10.1187/cbe.18-12-0250
18. Edgar, A.K., Macfarlane, S., Kiddell, E.J. et al. (2022). The perceived value and impact of virtual simulation-based education on students 'learning: a mixed methods study. BMC Med Educ 22, 823 (2022). https://doi.org/10.1186/s12909-022-03912-8
19. Edubirdie (2023). Major Advantages and Disadvantages of Using Virtual Reality in Education. (2022, September 01).. Retrieved July 12, 2023, from https://edubirdie.com/examples/major-advantages-and-disadvantages-of-using-virtual-reality-in-education/.
20. El-Sabagh (2018). The Impact of Web-Based Virtual Lab on the Development of Students ' Conceptual Understanding and Science Process Skills. https://d-nb.info/1013549376/34.
21. Fogg, N., Wilson, C., Trinka, M., Campbell, R., Thomson, A., Merritt, L., Tietze, M. & Prior, M. (2020). Transitioning from Direct Care to Virtual Clinical Experiences During the COVID-19 Pandemic. Journal of Professional Nursing 36, 685-691. https://doi.org/10.1016/j.profnurs.2020.09.012
22. Fransson, G., Holmberg, J., & Westelius, C. (2020). The challenges of using head mounted virtual reality in K-12 schools from a teacher perspective. Education and Information Technologies. https://doi.org/10.1007/s10639-020-10119-1
23. Gegios, T., Salta, K., & Koinis, S. (2018).Investigating high-school chemical kinetics: the Greek chemistry textbook and students' difficulties. Chemistry Education Research and Practice, 1(18), 151-168. https://doi.org/10.1039/C6RP00192K
24. Gurung, Rupa & Gurung, Bal. (2023). Laboratory Work and Its Impact in Learning Chemistry at Middle Secondary Schools of Trongsa, Bhutan. Asian Journal of Education and Social Studies. 48. 175-184. 10.9734/ajess/2023/v48i31078.
25. Hadzigeorgiou Y and Schulz RM (2019) Engaging Students in Science: The Potential Role of

"Narrative Thinking" and "Romantic Understanding". Front. Educ. 4:38. doi: 10.3389/feduc.2019.00038

26. Hough J, Levan D, Steele M, Kelly K, Dalton M. (2019). Simulation-based education improves student self-efficacy in physiotherapy assessment and management of paediatric patients. BMC Med Educ. 2019; 19:463.
27. Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. Education and Information Technologies, 23(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0
28. Jiang, J., Zhi, L., & Xiong, Z. (2019). Application of Virtual Reality Technology in Education and Teaching. Proceedings - International Joint Conference on Information, Media and Engineering, ICIME 2018, 300–302. https://doi.org/10.1109/ICIME.2018.00070
29. Kapur, R. (2020). Curriculum and Instructional Strategies in Education retrieve from https://www.researchgate.net/publication/339676252_Curriculum_and_Instructional_Str ategies_in_Education
30. Koch, J. (2018). Science Stories: Science Methods for Elementary and Middle School Teachers (6th ed.). Cengage Learning US. https://bookshelf.vitalsource.com/books/9781337517164
31. Lioce L. (Ed.), Downing D., Chang T.P., Robertson J.M., Anderson M., Diaz D.A., and Spain A.E. (Assoc. Eds.) and the Terminology and Concepts Working Group (2020), Healthcare Simulation Dictionary –Second Edition. Rockville, MD: Agency for Healthcare Research and Quality; January 2020. AHRQ Publication No. 20-0019. DOI: https://doi.org/10.23970/simulationv2
32. Loftin, D. (2018). 5 Ways 3D Models Can Help in Education. https://blogs.oregonstate.edu/inspire/2018/08/15/-ways-3d-models-can-help-in-education/
33. Lott, K., & Clark, S. (2019). Teaching Teachers: No Time for Science? Using an integrated approach to teach science inquiry. Science and Children, 57(1), 68–73. https://www.jstor.org/stable/26901499
34. Mabry J, Lee E, Roberts T, Garrett R. (2020) Virtual simulation to increase self-efficacy through deliberate practice. Nurse Educ. 2020; 45:202–5.
35. Matute-Vallejo, J., & Melero-Polo, I. (2019). Understanding online business simulation games: The role of flow experience, perceived enjoyment, and personal innovativeness. Australasian Journal of Educational Technology, 35(3), 71–85.
36. NSTA The Science Teacher—January/February 2023 (Volume 90, Issue 3). By Tyler Hansen, Deborah Fields, Amanda Strawhacker, and Yasmin Kafaiy. https://www.nsta.org/nstas-official-positions/role-e-learning-science-education
37. Okebukola, P. A., Suwadu, B., Oladejo, A., Nyandwi, R., Ademola, I., Okorie, H., & Awaah, F. (2020). Delivering high school Chemistry during COVID-19 lockdown: Voices from Africa. Journal of Chemical Education, 97(9), 3285-3289.
38. Oladejo, Adekunle. (2022). Approaches to Teaching Chemistry.https://www.researchgate.net/ publication/361789699_Approaches_to_Teaching_Chemistry
39. Oladejo, A.I., Okebukola, P.A., Olateju, T.T., Akinola, V.O., Ebisin, A., & Dansu, T.V. (2022). In Search of Culturally Responsive Tools for Meaningful Learning of Chemistry in Africa
40. Osman, K., & Ratamun, M., (2018) The effectiveness of virtual lab compared to physical lab in the mastery of science process skills for chemistry experiment. https://scientiasocialis.lt/pec/node/files/pdf/vol76/544-560.Ratamun_Vol.76-4_PEC.pdf
41. Parno; Mufti, N.; Widuri, K.A.; Ali, M. (2021) The effectiveness of experiential learning—STEM model with formative assessment in building students 'mastery on fluid dynamics. J. Phys. Conf. Ser.2021, 1816, 012051
42. Pareek, Ram Babu. (2019) An Assessment of Availability and Utilization of Laboratory Facilities for Teaching Science at Secondary Level. https://files.eric.ed.gov/fulltext/EJ1209309.pdf
43. Patel, Satish & Vaghela, Bhadreshkumar. (2021). Implementation of use of hand-made three-dimensional models to teach Anatomy with supplement to traditional methods with limited resources. Indian Journal of Clinical Anatomy and Physiology. 8. 298-300. 10.18231/j.ijcap.2021.064.
44. Penbhorn Kajornklin, Kitti Seeboonruang, Purim Jarujamrus. (2022). Learning Difficulties in High School Chemistry: The Case of Chemical Equilibrium International Journal of Science Education and Teaching Vol. 1, No. 3, pp. 121-127, Sep. – Dec. 2022 http://doi.org/10.14456/ijset.2022.11

45. Penn,Mafor & Ramnarain, Umesh. (2019). A comparative analysis of virtual & traditional laboratory chemistry learning. Perspectives in Education. 37. 80-97. 10.18820/2519593X/pie.v37i2.6.
46. Price, A., Wieman, C., & Perkins, K. (2019). Teaching With Simulations: Teachers use simulations for student motivation, content learning, and engagement in science practices. The Science Teacher, 86(7), 46–52. https://www.jstor.org/stable/26899147
47. Pujol, S., Baldwin, M., Nassiri, J., Kikinis, R., & Shaffer, K. (2018). Using 3d modeling techniques to enhance teaching of difficult anatomical concepts. Academic radiology, 23. https://doi.org/10.1016/j.acra.2015.12.012
48. Restiana, & Djukri,. (2021). Students 'Level of Knowledge of Laboratory Equipment and Materials. Journal of Physics: Conference Series. 1842. 012022. 10.1088/1742-6596/1842/1/012022.
49. Rooney, D., & Nyström, S. (2018). Simulation: A complex pedagogical space. Australasian Journal of Educational Technology, 34(6), 53–64. https://doi.org/10.14742/ajet.4470
50. Sipilä, J. (2020). University of Oulu. Information Processing Science Bachelor's Thesis 28.5.2020 Benefits and challenges of adopting virtual reality in primary education. http://jultika.oulu.fi/files/nbnfioulu-202005302244.pdf
51. Stratton, S. (2019). Quasi-Experimental Design (Pre-Test and Post-Test Studies) in Prehospital and Disaster Research. Prehospital and Disaster Medicine, 34(6), 573-574. doi:10.1017/S1049023X19005053
52. Sudarto, Sudarto. (2022). The advantages of humanistic science learning tools. International Journal of Trends in Mathematics Education Research. 5. 340-342. 10.33122/ijtmer.v5i3.129.
53. Suleman, et al., (2019). Development of Media 3D Visualization using Virtual Reality on Chemistry Education. https://doi.org/10.1088/1742-6596/1397/1/012034
54. Szott, A. (2018). Open-ended Laboratory Investigations in a High School Physics Course: The difficulties and rewards of implementing inquiry-based learning in a physics lab. The Physics Teacher 52, 17 (2014); https://doi.org/10.1119/1.48 49147.
55. Tamuang, S., Wuttisela, K., & Supasorn, S. (2018). Low-Cost Small-Scale Chemistry Experiment to Enhance 11-Grade Students 'Conceptual Understanding on Chemical Equilibrium (in Thai). Journal of Research Unit on Science, Technology and Environment for Learning, 8(2), 379–397.
56. Teplá, M., Teplý, P. & Šmejkal, P. Influence of 3D models and animations on students in natural subjects. IJ STEM Ed 9, 65 (2023). https://doi.org/10.1186/s40594-022-00382-8
57. Texas Education Agency TEA, (2023). Why Are Scientific Models Necessary? https://www.texasgateway.org/resource/scientific-models
58. Uchechi Bel-Ann Ordu 2021.The Role of Teaching and Learning Aids/Methods in a Changing World . New Challenges to Education: Lessons from Around the World BCES Conference Books, 2021, Volume 19. Sofia: Bulgarian Comparative Education Society ISSN 25348426 (online), ISBN 978-619-7326-11 6 (online) https://files.eric.ed.gov/fulltext/ED613989.pdf
59. Verkuyl M, Taplay K, Atack L, Boulet M, Dubois N, Goldsworthy S, Merwin T, Willett T, and Job T, Virtual Simulation: An Educator's Toolkit 2022
60. Vlachopoulos, D., Makri, A. The effect of games and simulations on higher education: a systematic literature review. Int J Educ Technol High Educ 14, 22 (2018).
61. Wangdi, D.; Tshomo, S.; Tshomo, P. (2020). Investigating Grade Nine Students 'Preferred Learning Styles Using a Kolb's Model. Bhutan J. Res. Dev. 2020, 9,43-58 https://www.researchgate.net/publication/346714806
62. Yuan, L. (2020). Identifying primary students 'alternative conceptions in science and promoting conceptual change using information and communications technology approaches. National Institute of Education Nanyang Technological University.
63. Zackoff MW, Young D, Sahay RD, Fei L, Real FJ, Guiot A, et al. (2021). Establishing objective measures of clinical competence in undergraduate medical education through immersive virtual reality. Acad Pediatr. 2021; 21:575–9.
64. Zhang, L., Li, Q., and Liu, W. (2022). A study on the effectiveness of college english teaching based on CBI teaching philosophy. Front. Psychol. doi: 10.3389/fpsyg.2022.921654
65. 10 Best Science Tools for High School. https://www.commonsense.org/education/lists/10-best-science-tools-for-high-school. Common Sense Education. July 2023