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Teaching and Learning with Computer Simulation in Secondary Schools in Nigeria: A Systematic Review

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Abstract

This systematic review examined 41 studies on teaching and learning with computer simulation in secondary schools in Nigeria across STEM subjects between 2020 and 2025. The study analyzed trends in research output, subject distribution, research designs, sample sizes, instruments, analytical methods and geopolitical distribution of studies in the field. Findings revealed a fluctuation in publications with the highest research activity recorded in 2025. Chemistry, Biology and Mathematics accounted for most of the studies. Quasi experimental pretest-posttest control group designs dominated the methodological approaches. Achievement tests were the most frequently used instruments, ANCOVA was the most used inferential analytical statistic. South-West zone recorded the highest number of publications in this review. Across the studies, computer simulation consistently improved academic achievement, conceptual understanding, retention, interest and positively affects the attitude of students. There seems to be limited studies in senior secondary schools on the use of computer simulation in technology-based subject like computer science and in the North-East and North-West geopolitical zones. Furthermore, studies conducted on teaching and learning with computer simulation were mostly experimental. This review recommends further research on the instructional effectiveness of computer simulations in computer science and underserved regions, and encourages educators, curriculum planners, and policymakers to adopt simulations for teaching complex, abstract, or hazardous concepts where real-life experimentation is difficult or impractical.

Keywords: computer simulation, systematic review, STEM, teaching, learning, schools

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1. Introduction

The essential role Information and Communication Technology (ICT) plays in the teaching and learning process, especially in science and technology education, cannot be overemphasized. In recent years, the integration of digital technologies in education has expanded significantly, especially within Science, Technology, Engineering and Mathematics (STEM) subjects. STEM subjects frequently involve abstract concepts, complex processes and problem-solving tasks that require learners to visualize relationships, test ideas and apply knowledge in practical contexts. Traditional instructional approaches often teacher dominated tends to limit opportunities for active engagement, experimentation and conceptual understanding (Chukwuemeka et al., 2025). As a result, educators and researchers have increasingly turned to technologies such as computer simulation as alternative innovative tools for strengthening students' learning outcome in STEM disciplines.

Computer simulations are dynamic interactive digital environments that represent real-world systems or scientific phenomena, enabling students to manipulate variables, receive instant feedback and observe outcomes in ways that may not be possible in physical classrooms or laboratories (Rutten et al., 2012). Okolo and Oluwasegun (2020) define it as a programme that imitates a thing, concept, process or situation of a model, especially for the purpose of teaching and learning. Computer simulations are the programmes that allow learners to systematically explore hypothetical situations, interact with those situations, and explore the changes occurring in the situations as a result of their interaction (Almasri, 2022). In STEM subjects, such as physics, chemistry, Biology, Mathematics, and Technology, simulations support visualization of invisible or abstract processes (Adams, et al., 2008). These help learners to move from surface level memorization to deep understanding, especially when dealing with difficult or hazardous experiments. Computer simulations give students the opportunity to observe a real-world experience and interact with it. They give students the opportunity to take initiative when learning about a given topic and create a teaching atmosphere where students are active (Ambelu & Gebregziabher, 2021). The incorporation of computer simulation modules provides a constructivist environment where students can study physical laws, demonstrate mental models, make predictions, derive conclusions, and solve problems (Guo, 2015). Computer simulation permits educators to create learning experiences that encourage learning in an environment that does not compromise learners' safety; it ensures that learners can build confidence and competence by offering a safe space for repeated practice (Cook, et al., 2012).

Over the years, numerous studies have been conducted on the use of computer simulations in teaching and learning specifically in STEM subjects with many reported significant improvements in learning outcomes (Arum, 2019; Ambelu & Gebregziabher, 2021; Cano, 2022; Niyigena & Nzabalirwa, 2022). However, findings are not entirely uniform. Some studies have reported minimal or no significant differences between simulation-based and traditional instruction, possibly due to differences in instructional design, level of guidance, simulation authenticity, learner readiness and teacher expertise (Rosali, 2020; Smetana & Bell, 2012). These inconsistencies highlight the need for a systematic review to provide a comprehensive synthesis of evidence on the use of computer simulations in teaching and learning in Nigerian senior secondary schools. A systematic review will enable researchers to collate, evaluate and analyze existing studies using transparent, replicable procedures by minimizing bias through clear inclusion criteria, rigorous search strategies and structured data extraction (Moher, et al., 2009). This offers a more reliable understanding of overall trends, dominant research designs, measurement instruments and the strength of evidence across context. Therefore, this systematic review aims to critically examine studies from 2020 to 2025 on teaching and learning with computer simulations in senior secondary schools in Nigeria, identify research gaps and provide recommendations to guide future studies, educators and policymakers.

This systematic review is guided by the following questions:

1) What is the trend in research on teaching and learning with Computer simulation in senior secondary schools in Nigeria from 2020 - 2025?
2) What is the distribution of the reviewed studies across STEM-related subjects?
3) What are the research designs used in the reviewed studies?
4) What are the sample sizes used across the reviewed studies?
5) What are the instruments used for data collection in the reviewed studies?
6) What are the methods of data analysis used in the reviewed studies?
7) What is the distribution of the studies across the six geopolitical zones in Nigeria?

2. Methodology

This study adopted a systematic review design to synthesize evidence on the use of computer simulations in teaching and learning of STEM subjects in senior secondary schools in Nigeria. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, 2020) protocol to ensure methodological transparency. A literature search was conducted across some academic databases; they include: Google Scholar, OpenAlex, Dimension and Springer link. The following keywords and Boolean operators were combined

to identify relevant studies: [“Computer simulation OR digital simulation OR simulation OR Instructional simulation”], [“Teaching OR learning”], [“STEM OR science education”] and [“Secondary school OR senior secondary school OR high school”].

2.1. Inclusion and Exclusion Criteria

Studies were included if they used computer simulation, published from 2020 to 2025, focused on STEM subjects and written in English language. Studies were excluded if they focused on primary, junior secondary or tertiary education, used only animations, videos or multimedia without simulations or provided insufficient methodological details.

A total of 1,297 records were identified through database searches. After removing duplicates, 1208 unique records remained for screening. Titles and abstracts were screened, resulting in the exclusion of 1101 records that did not meet the inclusion criteria. A total of 107 full text articles were assessed for eligibility. Of these, 66 were excluded for using other languages than English, not STEM-related subjects, not conducted in senior secondary schools in Nigeria and insufficient information. Finally, 41 studies met the full inclusion criteria and were included in the systematic review. Figure 1 shows the flow chart of the literature search.

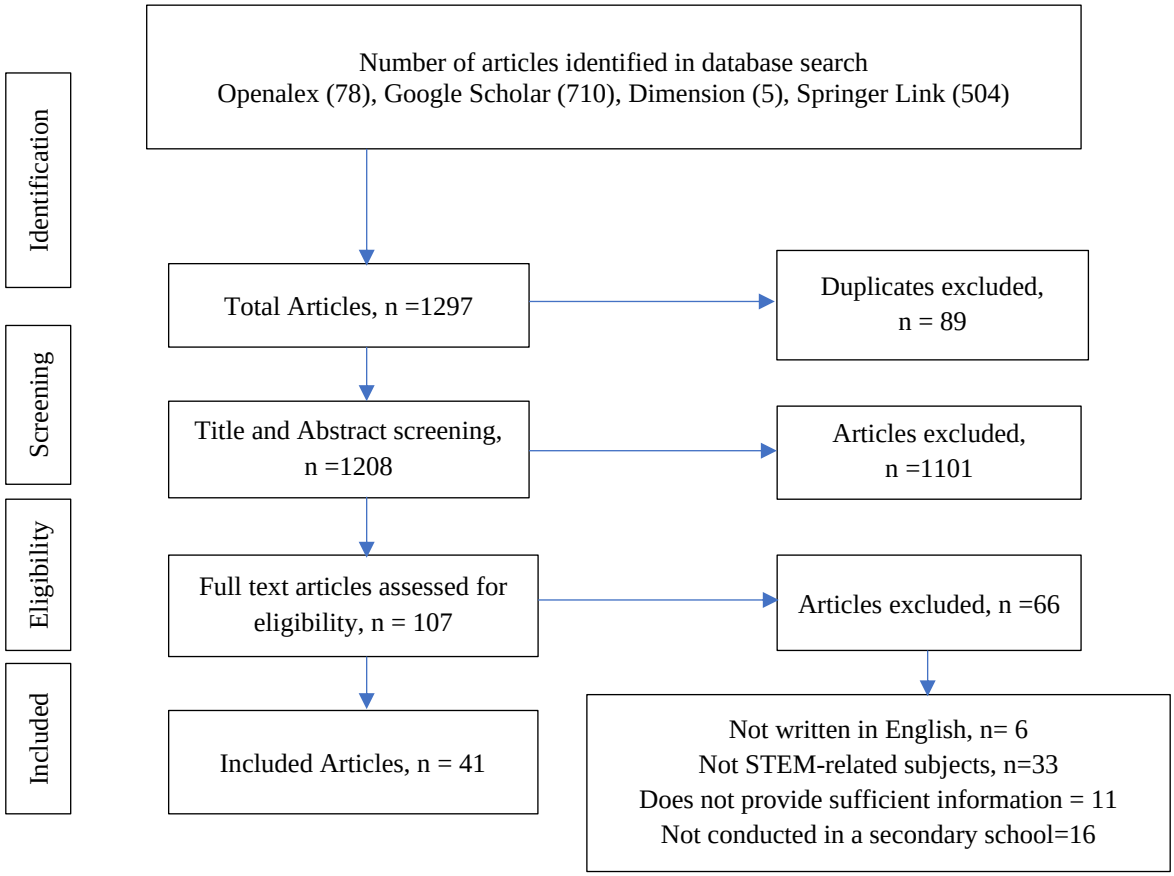

Figure 1. *Flow chart of the literature search*

2.2. Article Coding

In a coding sheet, relevant information from the research articles were coded. The following essential information were carefully recorded by the researchers: (1) authors (2) year of publication 3) Geopolitical zone (4) subject area (5) research design (65) Sample size used (7) instrument for data collection (8) method of data analysis.

Table 1. *Summary of Reviewed Literature*

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
1	Aduloiu et al	2025	South west	Investigated how well robotic-based computer simulations improve the instruction and learning of difficult scientific ideas in STEM education	Science subjects	Mixed	204	Test, classroom observation and interview	means, standard deviations, and independent t-test	A notable improvement in conceptual knowledge and academic performance for the experimental group was recorded
2	Abalas et al	2022	North-central	Examined the effects of simulation strategy on senior secondary school Biology academic achievement in Plateau Northern Senatorial Zone, Nigeria	Biology	Quasi-experiment	74	Human Circulatory System Achievement Test	means, standard deviations, ANOVA and ANCOVA	Simulation strategy improves students' achievement more than the traditional method of teaching Biology
3	Egara & Mosimege	2023	South-east	Examined how well learners retained algebra concepts after using a computer simulation program.	Mathematics	Quasi-experiment	115	test	Mean, standard deviation and ANCOVA	Students taught algebra using computer simulation had considerably higher average retention scores compared to learners taught utilizing the traditional method. Also, a significant gender difference occurred in the mean retention scores of students taught algebra concepts utilizing computer simulation.
4	Alabi et al	2023	North central	Investigated the influence of innovative simulations on students' performance and retention on their levels and gender	Physics	Quasi-experiment	55	Physic performance Test and Physics retention test	Mean, SD, t-test and ANCOVA	The use of computer simulation had a positive effect on the performance and retention of the students.
5	Fabeku & Enviasi	2024	South west	Examined computer simulation & video-media in improving students' performance in Chemistry & compared students' attitude towards Chemistry using the 2 packages.	Chemistry	Quasi experimental	138	Test and questionnaire	Mean, ANOVA and ANCOVA	There is significant difference between the experimental and control group in terms of performance and retention. No difference in students' attitude in the two groups
6	Ashiwere. et al.	2025	South-south	Examined the pedagogical effect of computer-animated simulation on students' academic performance in Biology among secondary school students in Cross River State, Nigeria.	Biology	Quasi-experimental	221	Biology Performance test	Mean, standard deviation and ANCOVA	There a significant difference in the performance of students taught using computer-animated simulation compared to the traditional lecture method. Both genders performed equally.

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
7	Oladeio. et al	2021	South-west	Investigated the effect of the use of computer simulation on learners' achievement in chemistry at the Senior Secondary School level	Chemistry	Quasi experiment	83	Test	ANCOVA	There is improvement in the performance of students taught using computer simulation.
8	Ogunbanwo et al	2025	South-west	Examines the impact of adaptive simulations on student learning outcomes, engagement, and satisfaction in secondary schools	Chemistry and physics	Mixed	166	Test and questionnaire	Mean, t-test and Pearson correlation	The results revealed that students taught using simulations achieved significantly higher pass rates in Chemistry and physics compared to traditional methods. Additionally, strong positive correlations were found between simulation adoption and both teacher perceptions and student engagement and motivation.
9	Alake. & Oloio	2020	South-west	Determine the effects of computer simulation package (CSP) on academic performance of senior secondary school students on the concepts of pollution and energy.	Science subjects	Quasi-experiment	600	Achievement test	Mean, SD and ANCOVA	The use of computer simulation package (CSP) has significant effect on students' academic performance while gender showed no significant influence on students' performance.
10	Okolo &	2020	North-Central	Investigated the 'Effect of Computer Simulation on Achievement & Interest in Cell Division among Male & Female Secondary School Students	Biology	Quasi-experiment	72	Cell Division Achievement Test and Cell Division Interest Scale	Mean, SD and ANCOVA	Computer simulation strategy was found to be better than the conventional method in teaching and learning of cell division; gender was not a determinant factor in Biology students' interest ratings in teaching cell division.
11	Egara et al	2022	South-east	Examined the effect of using computer simulation on students' interest in algebra	Mathematics	Quasi experiment	54	Algebra Interest Inventory	Mean, SD and ANCOVA	Interest scores of students taught algebra with computer simulation was significantly higher than those taught with the conventional method. No significant difference between the mean interest scores of male and female students taught algebra with computer simulation
12	Oladeio. et al.	2023	South-west	Investigated the use of computer simulation as an intervention to enhance the performance of female students relative to males in senior school	Chemistry	Quasi-experiment	83	Electrolysis and electroplating achievement test	Mean, SD and ANCOVA	No statistically significant difference between the performance of the male and female students.
13	Jack	2020	North-east	Investigated the effects of computer simulation, collaborative problem-solving and concept mapping on students' cognitive achievement in chemistry.	Chemistry	Quasi-experiment	229	Redox Reaction Achievement Test	Mean, SD, t-test and ANOVA	Students taught with computer simulation, collaborative problem solving and concept mapping had better results (achievement) than the control group that used the convention method.
14	Lasisi et al	2021	North central	Investigated the effect of innovative computer simulated instruction on students' academic performance in abstract concepts in science	Chemistry, physics. & Biology	Quasi-experiment	155	Science Concepts Achievement Test	Mean, percentage and t-test	Simulation enhanced students learning of abstract concepts than the use of conventional lecture method. Also, gender didn't influence academic performance of students who were taught with computer simulation.

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
15	Oveniran et al	2021	South-west	Determine the effects of Computer-based Simulations (CBSs) on the academic performance of senior secondary school students 'in Physics Practical.	Quasi-experiment	Physics	74	Physics Practical Performance Test	Mean, SD, ANCOVA, and ANOVA	CBSs had significant effects on students' academic performance in Physics practical. Sex has no significant influence on the effect of CBSs on students' academic performance in Physics practical.
16	Zumvil & Antip	2022	North-central	Investigate the effect of computer simulation and conventional Lecture instructional strategies on students' achievement & Interest in ecology in Plateau Central Education zone	Quasi-experiment	Biology	106	Ecology Achievement Test (E.A.T.) and an adopted Ecology Interest Inventory (E.I.I.).	Mean, SD and ANCOA	Significant effect of computer simulation strategy over the conventional lecture strategy in Ecology Achievement Test (EAT) was recorded. There was a significant effect on the interest rating scores of students exposed to computer simulation over the conventional lecture strategy in EII.
17	Omoedu et al.	2022	South-south	Examine the effect of computer simulation on students' academic achievement in chemistry in senior secondary schools in Ahoada-East Local Government Area, Rivers State.	Chemistry	Quasi-experiment	82	Chemistry Achievement Test	Mean and ANCOVA	Students taught with the computer simulation technique performed better than those taught with the traditional lecture method.
18	Marafa &	2023	North-west	Investigated the effect of simulations and instructional games on the academic achievement of senior secondary school students in mathematic	Mathematics	Quasi-experiment	200	Simulations & Instructional Games Mathematics Academic Achievement Test Scale	Mean, SD paired sample t-test	Instructional games positively affect students' academic performance in mathematics. Computer simulation has a statistically significant effect on students' academic performance in mathematics.
19	Yaki et al.	2020	North-central	Investigated the Effects of Computer Laboratory Simulation & Practical Demonstration Instructional Strategy on the Achievement of Secondary School Students in practical Biology.	Biology	Quasi-experiment	60	Biology Practical Achievement Test	Mean, SD and t-test	There is significant improvement in performance of the Experimental group. The simulation was Gender friendly.
20	Lawal. et al.	2025	North-west	Investigated the impact of computer simulation on students' performance & retention in Chemistry among secondary school students in Zaria Metropolis, Kaduna State	Chemistry	Quasi-experiment	30	Chemistry Performance Test and Chemistry Retention Test	Mean, SD and independent sample t-test	There is a significant difference between the mean scores of experimental and control groups in their academic performance, in favour of the experimental group.
21	Obaseki	2021	North-central	Investigation into effects of computer simulation on junior secondary school students' achievement and interest in algebra in Bosso Local Government Area, Niger State	Mathematics	Quasi-experiment	54	Algebra Achievement Test and Algebra Interest Inventory	Mean, SD and ANCOVA	Computer simulation approach in teaching affects students' achievement and interest in algebra. Also, there was no significant interaction effect between the teaching method and gender on students' achievement and interest in Algebra.
22	Ibitomi et al	2022	North-central	Investigates the effect of computer simulations on student performance in high school chemistry courses on the topic of chemical equations in Offa, Nigeria	Chemistry	Quasi-experiment	136	Chemical Equation Performance Test (CEPT) and Cognitive Force Checklist	Mean, SD percentage, t-test and ANCOVA	There are differences in the performance of students who are taught using computer simulations, between the performance of male and female students, and differences in performance between students who score low, medium, and high

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
23	Oioelade et al	2021	South-west	Investigated the effect of 3-dimensional computer simulation on secondary school students' academic achievement in chemistry, Ibadan Oyo State	Chemistry	Quasi-experiment	127	Chemistry Achievement Test (CAT) and Chemistry Retention Test	Mean, SD and t-test	There was significant difference in the mean achievement score of secondary school students taught chemistry using 3-D computer simulation and their counterparts in control group. There was no significant difference in the mean achievement score of male and female students taught chemistry using 3D-computer simulation.
24	Amaiu & Agommouh	2025	South-east	Investigate the effect of Computer Simulation Assisted Instruction strategy on achievement of students in physics	Physics	Quasi	93	Physics Achievement Test	Mean, SD and ANCOVA	Computer Simulation Assisted Instruction enhanced students' achievement in physics more than the TLTM. There was no statistically significant interaction effect of teaching strategies and gender.
25	Akinwumi	2024	South-west	Investigates the impact of the Instructional Simulation (INS) strategy on secondary school students' attitudes towards Biology in Ondo State, Nigeria	Biology	Quasi-experiment	151	Students' Attitude towards Biology Scale	Mean, SD and t-test	A significant difference in attitudinal mean scores between students exposed to instructional simulation and those using conventional methods, favouring the former. No gender difference in attitudinal mean scores of students using instructional simulation, nor was there a significant difference in attitudinal mean scores between students in rural and urban schools using instructional simulation.
26	Anari et al	2023	South-south	Examine the comparative impact of non-digital game-based learning (NDGBL) and Computer Simulation instructional methodologies on students' performance on the concept of chemical bonding in Calabar Education Zone, Nigeria.	Chemistry	Quasi-experiment	122	Chemical Bonding Achievement Test	Mean, SD and ANCOVA	Learners who were taught with non-digital game-based learning and computer simulation strategies did not differ significantly in academic outcome. There was a significant difference in the retention of students in the concepts taught using NDGBL and Computer Simulation in favour of students in the NDGBL group. Gender was also not found to be significant on students' learning outcome.
27	Nweze & Nnadi	2024	South-east	Investigated the effects of mode of computer simulation with on-screen text and narration (STN) and computer simulation with on-screen text only (ST) on students' achievement & interest in Chemistry in Enugu State.	Chemistry	Quasi	204	Chemistry Achievement Test (CAT) and Chemistry Interest Inventory	Mean, SD and ANCOVA	Computer simulation with on-screen text and narration (STN) was more effective than simulation with on-screen text-only (ST).
28	Raphael & Ahmed	2025	North-east	Investigated the effect of computer simulation instructional strategy on academic performance of senior secondary school's students in chemistry	Chemistry	Quasi-experiment	216	Chemistry Performance Test	Mean, SD and ANCOVA	There is a significant difference between the mean performance scores of Chemistry students taught with computer simulation strategy and those taught with the lecture method in Adamawa State. The simulation strategy was gender friendly.

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
29	Ovarinde	2024	South-west	Investigate the effect of computer simulation in an inverted classroom on students' academic performance in mathematics.	Mathematics	Quasi-experiment	195	Mathematics Achievement Test	Mean, SD t-test and ANCOVA	The experimental group significantly outperformed the control group.
30	Chukundah & Alibo	2024	South-south	Investigated the utilization of instructional simulation in the effective teaching and learning of sciences in secondary schools	Science	Descriptive survey	98	Questionnaire	Mean &SD	Graphic simulation was utilized to a high extent. Also, the extent of utilization of computer modeling and laboratory equipment's was equally to a high extent in teaching and learning of science subjects in secondary schools in Ekeremor Local Government Area of Bayelsa State.
31	Maniu	2020	North-east	Investigated the effects of interactive simulation strategy (ISS) on Senior Secondary school Students' attitude and achievement in mathematics.	Mathematics	Quasi-experiment	135	Mathematics Attitude Inventory Scale (MAIS) and Mathematics Achievement Test	Mean, SD and ANCOVA	ISS was effective on Senior Secondary Students' attitude and achievement in mathematics. Likewise, the use of ISS for teaching mathematics does not show any significant difference in attitude and achievement in mathematics amongst male and female students.
32	Isaac & Okoli	2025	South-east	Investigated effect of Virtual Simulation Instructional Technique on Secondary School Students' Academic Achievement in Biology	Biology	Quasi-experiment	93	Biology Achievement Test	Mean, SD and ANCOVA	Mean, SD and ANCOVA
33	Eiimonu et al.	2023	North-central	Investigated the comparative effects of computer-simulated strategy & real laboratory experiment (RLE) on students' achievement & retention in electricity practical	Physics	Quasi-experiment	103	Electricity Practical Achievement Test	Mean, SD and ANCOVA	The students taught electricity practical using CSE achieved and retained better than those taught using RLE
34	Shavau et al	2025	North-west	Determined the effect of computer simulation instruction on students' performance and retention in Biology.	Biology	Quasi-experiment	177	Ecosystem Achievement Test	Mean, SD and ANCOVA	The group taught with computer simulation instruction (CSI) had a better mean gain in performance and retention than their counterpart taught using lecture method.
35	Okove et al	2025	South-east	Investigated the effect of Computer Simulation Package (CSP) on academic achievement of students in physics.	Physics	Quasi-experiment	65	Physics Achievement Test	Mean, SD and ANCOVA	The experimental group taught physics with computer simulation package had higher mean achievement scores than the control group taught with lecture method.
36	Jack & Gamnioh	2020	North-east	Investigated effect of Computer simulation instructional strategy on Chemistry students' academic achievement in Acid-Base Reactions	Chemistry	Quasi-experiment	168	Acid-Base Reactions Achievement Test	Mean, SD and ANCOVA	There is significant difference in the mean achievement scores of students taught Acid-Base Reactions using Computer simulation than the Conventional method. Both genders performed equally when taught Acid-Base Reactions using Computer simulation.
37	Okigbo & Nwoke	2025	South-east	Investigated the effect of Simulation Model of Instruction on senior secondary school students' achievement in algebra.	Mathematics	Quasi-experiment	205	Mathematics Achievement Test	Mean SD and ANCOVA	Simulation Model of Instruction significantly improved students' achievement in algebra. The method was not gender-biased, as both male and female students benefited equally.

N	Author	Year	Zone	Purpose	Subject	Method	Population / Sample	Instrument	Data analysis	Key findings
38	Oveniran & Otevola	2023	South-west	Examined the effect of Computer-Based Simulations (CBSs) or Video Instructional Package (VIP) on secondary school students' attitude towards Physics.	Physics	Quasi-experiment	113	Physics Students' Attitude Questionnaire	Mean, SD an ANOVA	Mean, SD an ANOVA
39	Ndibe and Ezeliora	2021	South-east	Examined the effect of computer assisted simulation instruction on senior secondary school students' retention in Chemistry.	Chemistry	Quasi-experiment	160	Chemistry achievement test		Mean SD and ANCOVA students taught Chemistry using computer assisted simulation instruction performed better than those taught using lecture method. No significant difference in the performance of male and female students' retention in Chemistry
40	Sam & Stephen	2025	South-south	Examined the effect of PhET Simulation technology and gender on secondary school Physics students' academic performance	Physics	Quasi-experiment	202	Physics Performance Test	Mean, SD and ANCOVA	The study showed a significant difference in the academic performance of Physics students taught with PhET Simulation technology and those taught using expository method. Finding also showed a no significant difference in the performance of male and female Physics students taught with PhET Simulation technology and a no significant difference also exists in the academic performance of urban and rural Physics students taught with PhET Simulation technology.
41	Adebanio. et	2023	South-west	Examined the effect of computer simulation instructional package and gender influence on students' attitude towards biology.	Biology	Quasi-experiment	100	Biology Attitude Scale	Mean, SD, ANCOVA	Computer simulation instructional package had significant effect on attitude to biology. No significant main effect to of gender was found in students' attitude to biology.

3. Results and Discussion

This section presents the findings of the systematic review based on the studies that met the established inclusion and exclusion criteria. The results are synthesized and organized according to the objectives of the review.

3.1. Distribution of studies across the Years (2020 - 2025)

Table 2 and the accompanying graph (Figure 2) show the distribution of the 41 reviewed studies across the years (2020-2025). The trend shows that the pattern is fluctuating. In 2020 and 2021 the number of publications remain constant at 5 (12.2%) each. However, the number rises to 6 (14.6%) in 2022. A further increase is observed in 2023 with 9 (22.0%) publications. Interestingly, the trend dips sharply in 2024 to 4 (9.8%) publications making it the lowest point across the years. Despite this setback, the chart shows a significant rise in 2025 to 12 (29.2%) publications, the highest value recorded.

Table 2. *Number of Publications per Year*

Year	Number of Publication	Percentage (%)
2025	12	29.2
2024	4	9.8
2023	9	22.0
2022	6	14.6
2021	5	12.2
2020	5	12.2
Total	**41**	**100.0**

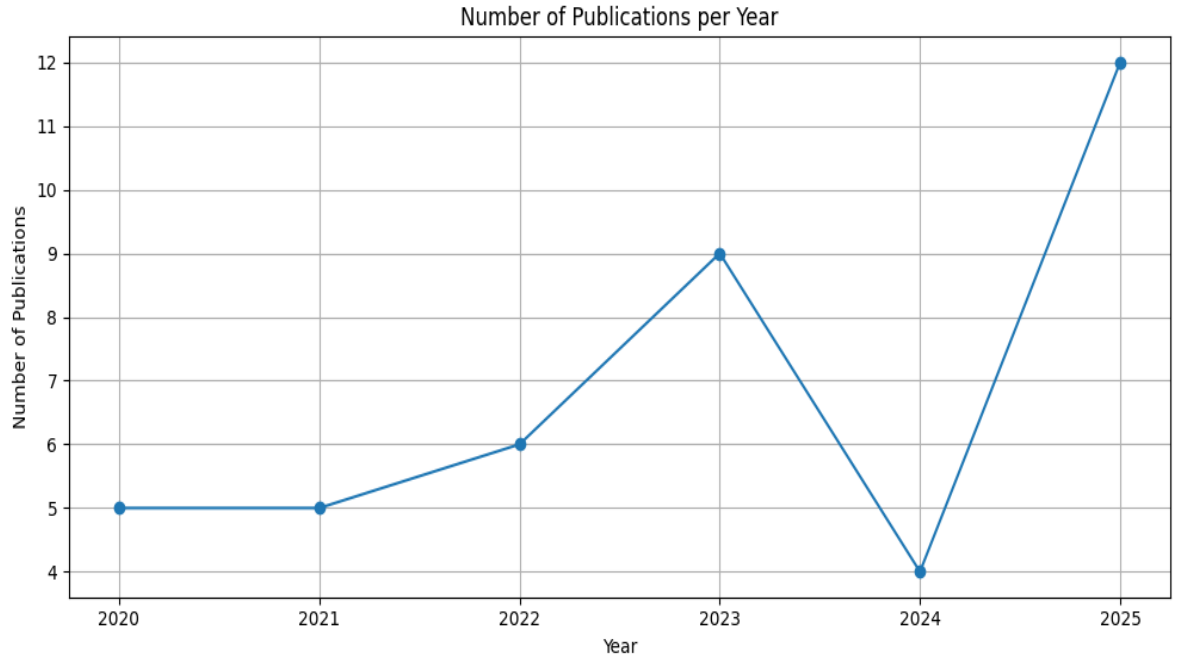

Figure 2. *A Line graph showing the trend of publications across the years*

Overall, the trend revealed by both the table and the graph suggests that research on teaching and learning with computer simulation in Nigeria secondary schools has gained significant progress over the years, with 2025 as the most productive period. This increase reflects growing global recognition of simulation as a vital educational innovation, particularly in response to the increased adoption of digital technologies in teaching and learning. The initial rise in studies after 2021 could be linked to global educational reforms and the shift towards technology-enhanced pedagogy driven by the COVID-19 pandemic, which compelled schools to integrate digital tools more broadly (Lawan & Zayyad, 2022). The pattern in the graph and table also suggests a paradigm shift in STEM education research, with increasing scholarly efforts devoted to exploring interactive, student-centered and technology-supported learning approaches (Abedalaziz, et al., 2013; Olasoji & Olatunji, 2023). The peak in 2025 indicates that simulation is not a passing trend but an emerging mainstream instructional practice.

3.2. Distribution of Studies across Subject Areas

Table 3 shows distribution of studies across subject areas. The studies span four major domains of STEM, namely: Chemistry, Biology, Mathematics, Physics. A key pattern observed across the subject distribution is that computer simulation was used as an effective tool in teaching and learning regardless of subject. However, the extent and nature of the utilization differed slightly across disciplines, revealing important insights into how simulation supports teaching and learning in each domain. Chemistry contributes the highest number of studies (13 studies; 31.7%), making it the most researched domain in the dataset. This is followed by Biology (9 studies; 21.9%), Mathematics (7 studies; 17.1%), and Physics (7 studies; 17.1%). General Science contributes 5 studies (12.2%), marking a moderate but relatively lower level of engagement compared to when the studies are conducted separately.

Table 3. *Distribution across Subject Areas*

Subject Area	Number of Studies	Percentage (%)
Chemistry	13	31.7
Biology	9	21.9
Mathematics	7	17.1
Physics	7	17.1
General Science (Biology, Chemistry and Physics)	5	12.2
Total	**41**	**100.0**

In Chemistry, simulations often replicate hazardous or highly complex laboratory processes. Studies reported enhanced conceptual understanding and retention in topics such as chemical reactions and bonding, and organic chemistry (Jack & Gamnjoh, 2020; Ibitomi et al, 2022; Anari et al, 2023; Okoye, 2025). Since Chemistry involves molecular-level interactions that are not easily observable in real life, simulations can enable visualization of atomic rearrangements, reaction mechanisms and chemical changes. This supports higher-order skills such as prediction, hypothesis testing and reasoning, which are critical for conceptual mastery (Jack, 2020; Oladejo, et al, 2021). Fabeku and Enyeasi (2024) added that simulation helps students to retain a great deal of visual information because they create and preserve a visual representation of it. This mental image helps students to do better academically. With chemistry being the top contributor, it suggests that researchers find chemistry particularly suitable for simulation-based teaching likely because of the abstract concepts in chemistry.

Many Biology topics require observation of biological processes that are either too small, too dangerous or too slow to observe directly. Simulation allows students to explore ecosystems,

anatomy, cells, and genetics without laboratory constraints. Another strength in the Biology studies was the reported increase in motivation and interest, suggesting that simulations also have affective benefits (Zumyil & Antip, 2022; Okolo & Oluwasegun, 2020; Adebanjo et al., 2023). This implies that biological learning benefits not only from the visualization features of simulations but also from the interactivity and engagement they provide (Abalas et al., 2022, Shayau et al., 2025).

Mathematics is another important discipline. Mathematics education research is traditionally robust because of the discipline's centrality to scientific thinking and problem-solving. Students frequently struggle with topics such as algebra, geometry, trigonometry, calculus and so on (Obaseki, 2021; Egara et al., 2022; Egara & Mosimege, 2023; Okigbo, & Nwoke, 2025). These challenges motivate researchers to develop new instructional approaches such as computer-assisted learning, visualizations, manipulatives, and problem-solving models in order to make mathematical concepts easy for students to understand. Mathematics requires logical reasoning, abstract thinking, and symbolic manipulation. These cognitive demands often form a basis for research into learning processes, misconceptions, and cognitive load (Manju, 2020). Mathematics is one of the subjects most commonly linked with digital tools such as graphing software, simulations, and dynamic geometry applications. This may explain its steady representation. Although Mathematics does not dominate the dataset, its representation suggests sustained research interest and recognition of the subject's critical role in STEM education.

Physics includes highly abstract concepts such as electricity, motion, waves, quantum ideas which students often struggle to grasp (Ejimonu et al., 2023, Sam & Stephen, 2025). These areas require visualization and experimentation for effective comprehension, which simulations are uniquely positioned to offer. Physics experiments often require specialized equipment, which may not be readily available in all schools. This could limit the frequency of research but simultaneously drive studies exploring alternatives such as virtual labs and low-cost apparatus (Oyeniran et al., 2021; Okigbo & Nwoke, 2023). The success of simulation in Physics-based studies can be attributed to the fact that it provides a virtual environment where students can manipulate variables and observe real-time responses. Therefore, simulation plays both cognitive and experiential roles in deepening conceptual understanding in Physics.

Across subject areas, simulation supports visualization of abstract concepts, interactive experimentation, problem solving and hypothesis testing, immediate feedback, and student engagement. This implies that simulation is a universally adaptable instructional approach across STEM fields. The successful integration across multiple disciplines strengthens the validity of the overall conclusion that simulation enhances academic achievement, retention,

engagement, problem-solving skills, interest and attitude regardless of subject specialization (Smetana & Bell 2018, Huang et al., 2020).

3.3. Research Design Used across the Studies

Table 4 presents the distribution of research designs used across the 41 studies. Quasi-experimental designs clearly dominate, accounting for 92.7% of all the sample (n = 38) while mixed-methods and descriptive surveys together account for only three studies.

Table 4. *Distribution of Research Designs*

Research Design	Number of Studies	Percentage (%)
Quasi-experimental	38	92.7
Descriptive Survey	1	2.4
Mixed Method	2	4.9
Total	**41**	**100.0**

This indicates that the majority of researchers investigating the use computer simulation in teaching and learning in Nigerian senior secondary schools adopted experimental procedures that involve pretest–posttest control group. The design allows researchers to measure learning gains attributable to the simulation intervention therefore providing strong evidence of causality. This is important because it demonstrates that the effect of simulation on learning outcomes is not merely correlational but can be attributed directly to instructional intervention (Oladejo, et al, 2021; Oyeniran et al., 2021; Abalas et al, 2022; Alabi et al, 2023). The second category was mixed-method. Mixed method provides deeper insights into both the quantitative and qualitative dimensions of learning. Mixed method allow triangulation between numerical achievement data and student perceptions, motivation or behavioral observations (Aduloju et al., 2025; Ogunbanwo et al., 2025). Although less frequent than quasi-experimental studies, their presence suggests an increasing interest in understanding not only whether simulations work but also how and why they influence learning. Only one study used descriptive survey as a research design. This tends to focus more on perception or opinion rather than measuring direct impact on achievement (Chukundah & Alibo, 2024). While this design contributes valuable contextual knowledge about simulation adoption in schools, it offers less causal evidence compared to the quasi-experimental studies.

3.4. Sample Sizes Across the Studies

Table 5 shows a clear distribution pattern in the sample sizes of the studies included in the review. A higher proportion of the studies employed moderate samples which accounted for 17

(41.5%) of the studies. Large size represents 8 (19.5%) of the studies. Sixteen studies employed small samples, which is common in school-based experimental research where intact classes are used.

Table 5. *Distribution of Sample Size*

Sample Size	Range	Frequency	Percentage (%)
Small	1-100	16	39.0
Moderate	1101-200	17	41.5
Large	Above 200	8	19.5
Total	--	**41**	**100.0**

Small samples are often ideal for pilot studies classroom-based interventions. They aligned with the recommendations in experimental research that moderate sample sizes offer reasonable statistical power and reliability (Creswell & Creswell, 2018). Studies with moderate sample sizes typically employed quasi-experimental pretest-posttest designs, which require comparing performances between treatment and control groups. The presence of studies with large sample sizes suggests high external validity and broad applicability across different school contexts. This classification conforms to Mugenda and Mugenda (2003) and Fraenkel and Wallen (2014), who argued that large samples increase generalizability and accuracy in educational research.

A review of the findings shows that simulation interventions are used across diverse samples sizes, from small classroom trials to large school populations. This enhances the robustness of evidence supporting computer simulation as an instructional approach in STEM education.

3.5. Types of Instruments Used across the Studies

Table 6 shows the summary of instruments used across the 41 studies. The most dominant instrument used was the achievement test, which appeared in 28 (68.3%) of the studies.

Table 6. *Distribution of Instruments for Data Collection*

Instrument	Frequency	Percentage (%)
Achievement Test Only	28	68.3
Test + Interest Scale	4	9.9
Test + Questionnaire	3	7.3
Test +Observation + Interview	1	2.4
Test + Checklist	1	2.4
Questionnaire Only	3	7.3
Interest Inventory Only	1	2.4
Total	**41**	**100.0**

This clearly indicates that most researchers in this field focus primarily on cognitive learning outcomes such as academic achievement, performance and retention. (Jack, 2023; Omoedu et al., 2022). Achievement tests also align well with the purpose of simulated-based studies, which typically aim to determine whether the instructional intervention improves learning of specific STEM concepts. A proportion of the studies supplemented achievement tests with interest scale (9.9%), and questionnaire (7.3%). These instruments capture affective construct such as attitude or perception (Fabeku & Enyiasi, 2024; Akinwumi, 2024; Ogunbanwo et al, 2025). The use of these additional data collection tools reveals that many researchers recognize that simulation impacts learners not only intellectually but also in terms of emotionally. The least frequently used instruments were a combination of test with checklists, observation and interview, and interest inventory with 2.4% each. Their presence indicates a growing interest in evaluating students' level of engagement and attraction toward computer simulation in STEM learning as it affects their academic achievement in schools (Obaseki, 2021; Zumyil & Antip, 2022). Through classroom observation and interview, additional data that provide behavioural and explanatory insights into students' learning experiences are explored (Ejimonu et al., 2023). Three (7.3%) studies used questionnaires only (Oyeniran & Oteyola, 2023; Chukundah & Alibo, 2024, Akinwumi, 2024) and one study (2.4%) utilized interest scale only for data collection (Egara, et al, 2022). These studies were conducted primarily to assessed how computer simulation affects students' attitude and interest as they are used in the classroom.

The distribution of instruments shows that researchers in simulation studies in Nigeria tend to favour quantitative methods, using particularly achievement tests, for evaluating instructional outcomes. However, the inclusion of multiple instruments in few studies signals an emerging shift toward more comprehensive data collection approaches that combine cognitive and affective measurements. This trend strengthens the validity of findings and provides a more holistic understanding of how simulations influence students learning.

3.6. Methods of Data Collection used across the Studies

Table 7 demonstrates that researchers selected analytical methods that aligned closely with their research designs. All the 41 studies employed descriptive statistic of mean and standard deviation to answer research questions in the reviewed studies. Most studies employed inferential statistics such as ANCOVA, t-test and ANOVA to test for significant differences between treatment groups and control groups.

The preference of ANCOVA may largely be due to its strength in controlling for initial group differences, particularly in quasi-experimental designs where intact classes are always used

(Alake & Olojo, 2020; Nweze & Nnadi, 2024; Amaju & Agommouh, 2025; Isaac & Okoli, 2025). This adjustment enhances the accuracy of treatment effect estimates and ensures that any significant difference observed between the experimental and control groups is attributed to the instructional intervention rather than pre-existing differences among participants (Pallant, 2020). Only one study combined t-test and thematic analysis of interview responses to explore students' experiences with computer simulations (Aduloju et al, 2025). This indicates that the field favours statistically rigorous methods suitable for establishing causal effects of computer simulations on students' learning outcomes.

Table 7. *Distribution of Method of Data Analysis*

Method of Data Analysis	Frequency	Percentage (%)
Mean + SD + ANCOVA	22	43.7
Mean + SD +t-test	5	12.2
Mean +SD+ ANCOVA+ANOVA	3	7.3
Mean +SD+ANOVA	2	4.9
Mean+Percentage+t-test	2	4.9
Mean + SD	2	4.9
Mean +SD+ ANCOVA+t-test	2	4.9
Mean +SD+ ANOVA+t-test	1	2.4
Mean +t-test+Pearson Correlation	1	2.4
Mean + SD +t-test+Thematic Analysis	1	2.4
Total	**41**	**100.0**

3.7. Reviewed Studies across Geopolitical Zones

Table 8 and the corresponding pie chart in figure 3 show the distribution of studies across the six geographical zones in Nigeria. The South-West dominates simulation-based research with 11 (26.8%) out of the 41 studies. The zone's leadership suggests that simulation-based learning is more entrenched and better supported in the South-West than in other regions. North-Central is the second contributor with 9 (22.0%) studies, followed by South-East with 8 (19.5%) of the total studies. South-South, North-East and North-West contributed 6 (14.6%), 4 (9.8) and 3 (7.3%) studies respectively. North-West is the least contributor in research on the use of computer simulation in teaching and learning in STEM education.

The distribution of studies across the six geographical zones in Nigeria is uneven with a noticeably higher concentration of studies originating from South-West geopolitical zone (Alake, & Olojo, 2020; Ojolade et al., 2021; Oladejo et al., 2023). The dominance of South-West can be attributed to a combination of institutional, infrastructural, socio-economic and educational

factors that collectively shape research productivity and implementation of technology-driven institutional interventions in the region. North-Central is the second most productive zone in the field. A key factor contributing to the presence of studies in North-Central Nigeria is also the strategic concentration of federal institutions and educational research centres, particularly in states like Kwara, Plateau and the Federal Capital Territory (Abuja). The presence of these institutions provides a stable academic environment for postgraduate research where technology-based instructional innovations are frequently explored. North-West recorded the lowest number of studies in the field (Marafa & Suleiman, 2023; Shayau et al., 2025; Lawal, et al., 2025). Several contextual factors may account for the low output of study in the use of computer simulation in teaching and learning in the region. These factors may include, but not limited to insufficient ICT infrastructure in many schools, lower access to computer laboratories and varying level of teacher ICT competence. Additionally, in recent years, security challenges in the region have also constrained sustained school-based research, particularly studies that required repeated visits and controlled interventions (UNESCO, 2022).

Table 8. *Distribution of the Reviewed Studies across Geopolitical Zones*

Geopolitical Zone	Frequency	Percentage (%)
South-West	11	26.8.7
North-Central	9	22.0
South-East	8	19.5
South-South	6	14.6
North-East	4	9.8
North-West	3	7.3
Total	**41**	**100.0**

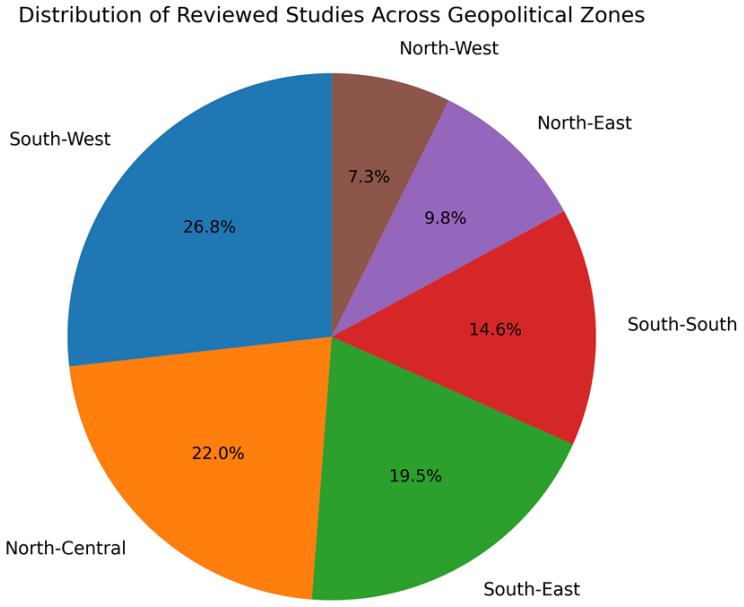

Figure 3. *Distribution of the Reviewed Studies Across Geopolitical Zones in Nigeria*

4. Conclusion

Computer simulation refers to applications that run on computers to display a model of a real-world system. The basis for simulation is to create a virtual version of natural and real-life processes or concepts on a computer. It is an important strategy especially in a situation whereby the real system is complex, expensive or non-available. The recent trend in research on computer simulation in relation to teaching and learning shows that there is an increase in research on this topic from 2020-2025. This increase reflects growing global recognition of simulation as a vital educational innovation, particularly in response to the increased adoption of digital technologies in teaching and learning connected with the emergency adoption of virtual instructions in the COVID-19 lockdown globally. Across subject areas, simulation proved beneficial regardless of disciplines. The dominance of quasi experimental designs and the wide spread use of achievement tests further strengthen the reliability of the evidence, indicating that improvements in learning are causally linked to simulation interventions rather than chance occurrence. The dominance of South-West suggests that simulation-based learning is more entrenched and better supported in the region than in other regions because of some advantageous factors. Overall, the findings provide convincing evidence that computer simulation is not only a supportive instructional tool but a transformative one.

Despite the benefits of computer simulation highlighted in the studies, there seems to be limited studies in technology-based subject such as digital technologies. Secondly, studies in secondary schools on the use of computer simulation seems to be limited in the north-eastern and north-western geopolitical zones of Nigeria. Thirdly, studies conducted on teaching and learning with computer simulation were mostly quantitative, no pure qualitative studies is found. Finally, the review was limited to open access publications, which may introduce a potential selection bias by excluding relevant studies available only through restricted-access databases or subscription-based sources.

Based on the findings, this review recommends the need for more studies to be conducted on computer simulation in technology-based areas like computer science so as to add to the existing body of knowledge on the instructional effectiveness of computer simulation in secondary education. Qualitative researchers should take advantage of the limitation to conduct studies using qualitative design to gain a more comprehensive understanding of the role of computer simulation in teaching and learning in Nigeria. Also, it is recommended that studies in the use of computer simulations in teaching and learning are to be conducted in those zones that are lacking behind. Furthermore, it is recommended that educators, curriculum planners

and policymakers adopt simulations particularly for complex, abstract or hazardous concepts where real-life experimentation is difficult or impossible.

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