Effect of Computer-Based Simulation on Learning Outcome: A Systematic Literature Review

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Abstract

Computer-Based Simulation (CBS) instruction strategy is a technological innovation which is a form of pedagogy to aid meaningful learning towards achievement of educational goals. The purpose of this study is to review recent advances in research on CBS instructional strategy in the period from 2018 to 2022. This paper uses systematic literature review (SLR) for the collection and evaluation of relevant primary studies in a transparent and reliable manner. The SLR is guided by a review protocol as the criteria for collection of related primary studies and literature content evaluation in a systematic way. The results show that the number of publication on this topic rises consecutively in 2019 and to its highest value in 2020 in the reviewed period from 2018 to 2022. The study shows that physics received the highest attention and followed by biology in the reviewed period. Furthermore, the results revealed that most researchers used quasi-experimental research design and quantitative research method with achievement test as the method of data collection in the reviewed period. Finally, in view of impractical nature of some biological concepts, it is recommended that further research be conducted on development and effective use of computer programmes to simulate complex biological processes that may not be observed in real life.

*   **Keywords:** *Computer-Based Simulation, Computer Simulation, Systematic Literature Review, Learning Outcome, Academic Achievement.*

1. Introduction

In order to achieve the goals of teaching and learning, there is a great need for integration of technological innovations in teaching strategies as a form of pedagogy to bring about meaningful learning which could improve learning. Instructional strategies used by teachers in teaching-learning process have significant influence on students' academic achievement. Most teachers are still using the traditional (conventional) teaching method which rendered the teaching process passive and look more of an abstract have failed to enhance problem-solving skills, curiosity, critical and logical thinking among the science students [1]. There are many ways that teachers can implement instruction in the classroom to ensure that learners gain the targeted skills and knowledge to prepare learners for real life world. Improved teaching strategies

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might help reverse this trend of poor achievement. Such strategies include computer simulation and other related technological innovations.

Simulation refers to imitation of situation or process, it is a technique that teaches concepts by imitating or replicating the real objects. For example, simulation of blood flowing through arteries or an electron revolving round the outer part of an atom. This may be as a result of non-availability of real objects, complexities in making use of real materials, abstract nature of the concepts, long distance and time involved in getting the real materials. Where any of the instances mentioned above occurs, simulation may turn out to be a better alternative. Computer Simulation is a program that attempts to simulate an abstract model of a particular system [2]. Computer simulations are therefore computer- generated versions of real-world objects.

Computer simulation which is a representation or model of an event, object, or some phenomenon plays a very significant role in preparing individuals for life. Computer simulations enable learners to view events, processes and activities, that otherwise may not have been available to them through interactive engagement. Computer simulation brings into the classroom, aspects of the real world or universe that are too expensive, dangerous, difficult, too slow or too fast in occurrence to be experienced first-hand. Thus, extravagance and possible accidents are prevented [3]. Computer simulation permits educators to create learning experiences that encourage learning in an environment that does not compromise learners' safety. Computer simulation incorporates multimedia elements such as graphics, animation, static pictures, simulation, photos, videos, text and narration on the computer screen [4].

Computer aided instructional media such as computer simulations have been identified as an effective instructional media for enhancing students' learning of difficult and abstract concepts [5]. The media facilitate the teaching and learning of abstract concepts because it is specifically designed to help students visualize abstract concepts. The media create some virtual models of an observed phenomenon, which promote learners' understanding of concepts and processes. The inclusion of simulations in education programs has many contributions, according to Olumide [6] computer simulations are interesting and contribute to students' problem-solving and decision-making skills. In addition, the simulation contains many applications that appeal to many senses, like diagrams, graphs, animations, sounds, and videos, which can make learning easier.

This paper reviews the effect of computer-based simulation instruction strategy on learning outcome for the period of five years from 2018 to 2022. The objective of this study is to: i) identify recent research trends on CBS in relation to learning outcome in the years from 2018 to 2022; ii) identify the subject areas' learning outcome investigated with CBS in the reviewed period from 2018 to 2022; iii) determine the research methods used for investigating CBS on learning outcome from 2018 to 2022; iv) identify the popular instruments for data collection used in research on effect of CBS on learning outcome from 2018 to 2022; v) identify the research designs applied for research on effect of CBS on learning outcome from 2018 to 2022. The remaining part of this paper is organized as follows; section 2 provides review

of related studies. Section 3 outlines the research method for this systematic literature review (SLR). Section 4 is for results and discussions of this study and finally section 5, which concludes the paper.

2. Related Studies

Most studies conducted in the reviewed period found out that computer based simulation (CBS) enhances learning outcomes in physics ([7]; [8]; [9]; [10]; [11]; [12]). Studies that focus on different aspect of learning physics discovered that CBS overcomes learning misconception ([13]; [14]) and improves learning attitude [15]. Whereas, Yehya, et al. [16] investigated the effectiveness of CBS with hand-on activities compared to CBS alone by an experimental design with post-test only. The author used achievement test for data collection and discovered that CBS with hand-on proved to be more efficient than CBS only.

Studies that focus on biology are Akhigbe and Ogufere [17] that investigated the effect of computer simulation on senior secondary school students' academic achievement in biology by quasi-experimental design and questionnaire. The author discovered that CBS significantly improves the academic achievement of biology students. Furthermore, CBS bridges the gap in learners' attitude and achievement of male and female students. Also, Komarova [18] evaluated the use of CBS model for teaching genetics. The results of the evaluation shows that CBS enhances the understanding of genetics and evolution processes which most students perceive difficult. Similarly, Awodun and Oyeniyi [19] discovered that CBS has significant effect on the academic performance of biology students.

An effort to investigate the effect of CBS on interest and achievement of biology students by Okolo and Oluwasegun [20] used quasi-experimental design with achievement test and interest scale questionnaire. The results show that CBS proved to be better than conventional method of teaching and learning biology. In addition, the study discovered that there is no significant difference in interest of learning biology between male and female students. Whereas, Olumide [21] studied the effect of CBS and digital puzzle packages on students learning outcome in biology by quasi-experimental research design using achievement test and questionnaire for data collection. The author discovered that CBS enhances learners' academic achievement and attitude in biology. The results of Studies have also discovered that CBS instructional strategy can enhance learners' academic performance in chemistry and there is no significant difference in gender performance ([22]; [23]). Egara, et al. [24] examined the effect of CBS on students' interest in algebra. The study discovered that CBS can enhance learners' interest in mathematics. Furthermore, the study discovered that there is no significant difference between male and female students' interest in learning mathematics with CBS.

Studies that focused on other levels of education systems include a lower level study by Ojo [25] to determine the effect of CBS instructional strategy on primary school pupils' academic achievement in basic science used quasi-experimental research design with achievement test instrument for data

collection. The author found out that CBS significantly improves pupils' achievement in basic science. Also, a higher level studies on vocational and technical education used quasi-experimental research design. Particularly, a study by Samsudin, et al. [26] investigated students misconception using CBS learning strategy on dynamic electricity PDEODE (predict, discuss, explain, observe, discuss and explain) with achievement as the method of data collection. The findings of the study revealed that CBS by PDEODE reduces learners' misconception frequency on dynamic electricity. Whereas, Nwineh and Okwelle [27] compared the effectiveness of CBS and demonstration instruction approach for vocational and technical education at the university level. The result shows that CBS improves practical skills in domestic technical installations. Similarly, Siam and Abdo [28] found out that CBS enhances engagement, cooperation and autonomy of electrical engineering undergraduate students.

Studies on nursing education conducted by Edeer and Sarikaya [29] investigated the view, perception and recommendation of nursing education students using qualitative research method by focus group interview. The result shows that CBS is beneficial for learning and practice of nursing profession. Similarly, Choi, et al. [30] compared the efficacy of CBS, communication education and attention control programs for nursing education students by mixed method using quasi-experimental research design and content analysis method of qualitative data collection. The result shows that communication education program is more efficient for nursing students learning. Overall, studies proved that the use of CBS packages for instruction is beneficial. Consequently, what is worth doing is worth doing well. Therefore, further study to in cooperate the diversity CBS packages for teaching and learning of different subjects' at all educational levels is crucial.

3. Methodology

SLR is a type of review that uses repeatable research method for collection and analysis of primary studies in transparent and unbiased manner. SLR is guided by a review protocol that covers the method of literature collection and literature content evaluation in a systematic way. The review protocol sets important criteria for highly rigorous evaluation of literature on the subject area that helps in identifying research gaps and directing further researches.

3.1. Review Protocol

Review protocol provides an outline of the procedures of carrying out the review. It guides the reviewer on critical decisions by a step-by-step plan for reliable collection and evaluation of relevant primary studies. This review plan reduces the risk of selecting irrelevant literature and introduction of bias in the review. This review protocol covers review questions, search strategy, inclusion and exclusion criteria, primary studies selection, quality assurance and data extraction.

a) Review Questions (RQ)

RQ1- What is the recent trend in research on the effect of CBS on learning outcome from 2018 to 2022?

RQ2- What are the subject areas investigated with CBS in the reviewed period from 2018 to 2022?

RQ3- What are the research methods used for investigating CBS on learning outcome from 2018 to 2022?

RQ4- What are the instruments for data collection used in research on effect of CBS on learning outcome from 2018 to 2022?

RQ5- What are the research designs applied for research on effect of CBS on learning outcome from 2018 to 2022?

b) Search Strategy

The search string for this review is :

('Computer-based simulation' OR 'computer simulation' OR 'Simulation Packages') AND ('Learning outcome' OR 'academic performance' OR 'academic achievement')

c) Inclusion and Exclusion Criteria
Inclusion Criteria
i) Primary studies are related to CBS on learning outcome.
ii) Primary studies should be published from 2018 to 2022.
 iii) Primary studies are written in English languages, or have their translation into English language.

Exclusion Criteria
i) Primary studies are not relevant to the review questions.
ii) All primary studies published before 2018 and after 2022.
 iii)Primary studies written in other languages, except English language translation is available.

d) Primary Studies Selection

All primary studies that investigated CBS on learning outcome or academic performance or academic achievement from 2018 to 2022 will be included in the inclusion list. Conversely, any primary studies that did not investigate CBS on learning outcome and published before 2018 and after 2022 will be excluded in the inclusion list.

e) Quality Assurance

All full text of selected primary studies that investigated CBS on learning outcome from 2018 to 2022 will be searched, filtered and gathered. First, the inclusion and exclusion criteria will be applied to remove irrelevant studies in the search engines. Second, all primary studies that satisfied the inclusion and exclusion criteria will be gathered in Mendeley reference manager to remove duplicates. Further quality assessment will be conducted to ensure the relevance and quality of all included primary studies.

f) Data Extraction

Sequel to application of data quality assessment criteria, this is followed by extraction of data from the selected primary studies. An outline of data extraction procedures is as follows;
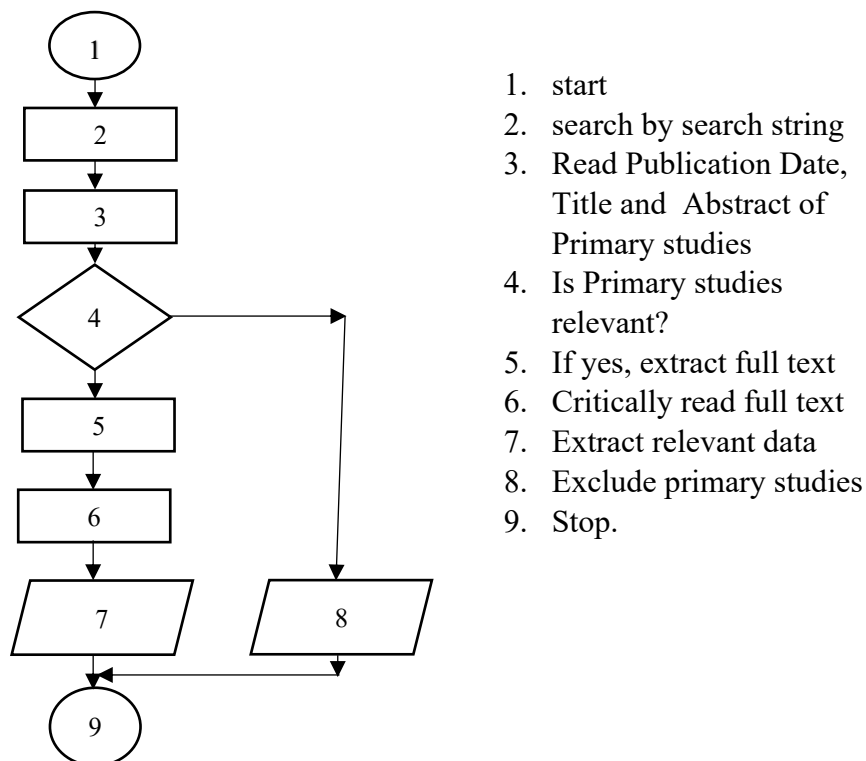
i) Examine the title, Abstract and publication date of potential relevant primary studies.
ii) Retrieve full text of relevant primary studies.
iii) Critically evaluate selected primary studies to ascertain its eligibility.
iv) Extract publication date, subject area, research method, research design and instrument for data collection used.
v) Record retrieved data on the Data Extraction Form shown on Table 1.

Table 1. Data Extraction Form

Title	
Author	
Publication Date	
Subject Area	
Research Method used	
Data Collection instrument	
Research Design Used	

3.2. Conduction of the Review

In compliance with the review protocol, the search of primary studies is guided by the flowchart shown in Figure 1.

1. start
2. search by search string
3. Read Publication Date, Title and Abstract of Primary studies
4. Is Primary studies relevant?
5. If yes, extract full text
6. Critically read full text
7. Extract relevant data
8. Exclude primary studies
9. Stop.

**Figure 1. Flowchart for Research Procedure**

4. Results and Discussions

This section contains description of the main findings of the review as well as interpretation of the results. The section contains the following subheadings; first subheading is the research trends in the period from 2018 to 2022. Second

subheading provides the results of the subject areas investigated in the reviewed period. Third subheading is for the findings on the research methods used in the reviewed period. Fourth subheading shows the results on instrument for data collection used in the reviewed period. The final subheading summarize the research design used in the reviewed period.

4.1. Research Trend

Table 2. Number of Publications per Year

YEAR	NUMBER OF PUBLICATIONS
2018	6
2019	7
2020	8
2021	5
2022	1
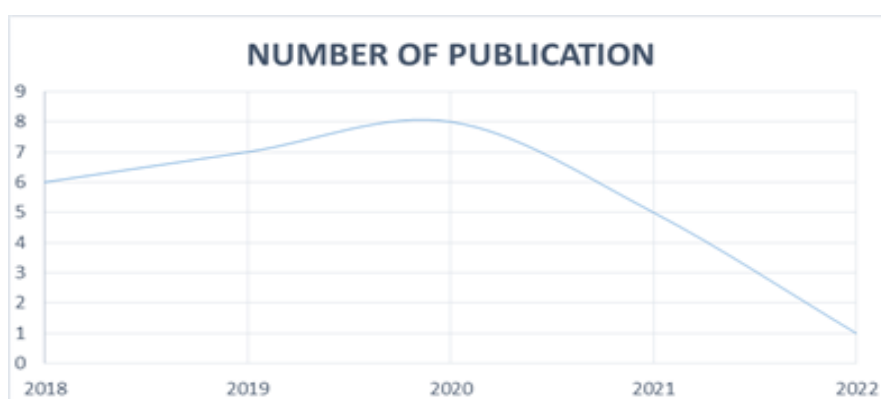
Figure 2. A Line Graph Indicating Number of Publications per Year

The line graph in figure 2 shows the number of publications made in the period from 2018 to 2022. The line graph provides information on the recent trend of research conducted and published in the reviewed period. First, the graph shows that six publications were made on CBS in relation to learning outcome in 2018. The number rises consecutively for two years in 2019 to seven and the highest number of publications of eight in 2020. Then the number of publications dropped steadily to five in 2021 and the least number of publication of one in 2022. Overall, the highest publications of eight were made in 2020 and the lowest publication of one was made in 2022.

4.2. Subject Areas Investigated

The pie-chart in figure 3 represents the composition of subject areas investigated by researchers in the reviewed period. Each portion in the circle represents the number of publications made for the subject areas investigated. First, the pie-chart shows that 41 percent of researchers investigated the effect of CBS on learning physics. Second, 22 percent of researchers focused on investigating the effect of CBS on biology students learning outcome. Third, eight percent of the publications investigated the effect of CBS on learning

outcome in chemistry. Fourth, seven percent each of the researchers investigated on CBS on learning outcome in basic science, nursing and technical education. Finally, four percent of the publications focused on investigating CBS on learning outcome in mathematics and electrical engineering at the university undergraduate level. In a nutshell, physics received the highest attention in the reviewed period and followed by biology. Mathematics and electrical engineering recorded the least attention in the period from 2018 to 2022.

Table 3. Number of Publications per Subject Area

SUBJECTS	NO. OF PUBLICATIONS
Biology	6
Physics	11
Chemistry	2
Mathematics	1
Basic Science	2
Technical Education	2
Electrical Engineering	1
Nursing	2
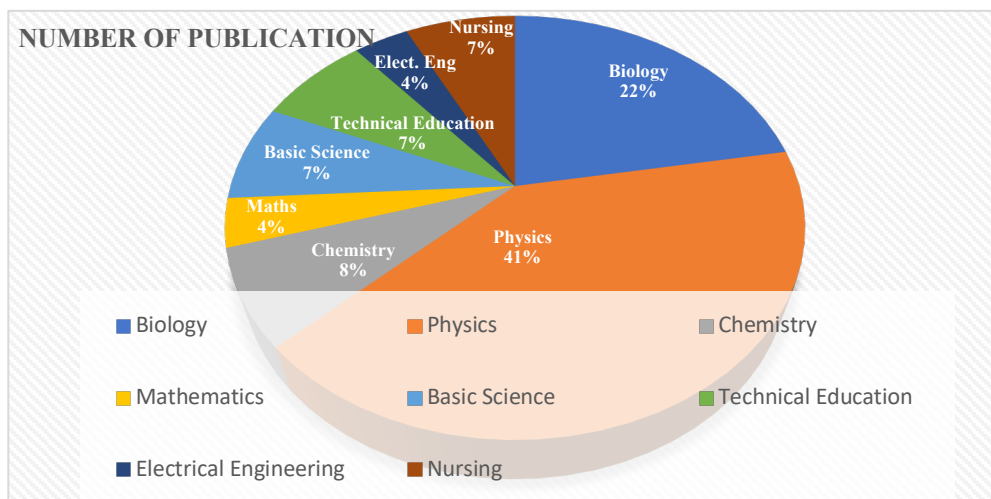
Figure 3. Pie Chart for Number of Publications per Subject Area
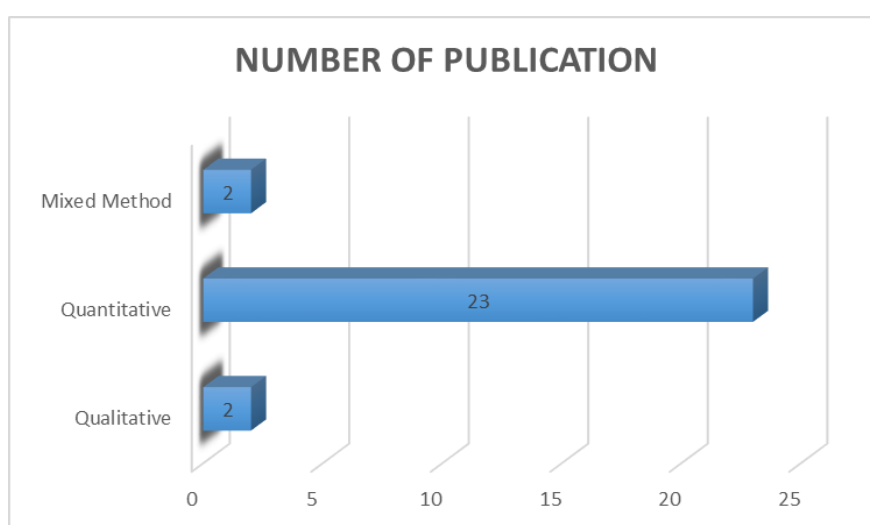
4.3. Research Method Used

Generally, there are three types of research methods namely; qualitative, quantitative and mixed research methods. These are the methods used in collection of data for further analysis and evaluation. Qualitative research method gathers non-numerical data with focus on establishing relationship and patterns. On the other hand, quantitative research method gathers numerical data for measurements of variables for cause-and-effect's evaluation or establishing relationship between variables. Whereas mixed research method is the use of both qualitative and quantitative research methods for better

explanation of results. This subsection determines the kind of research methods used for research on CBS in relation to learning outcome in the period from 2018 to 2022. The results as shown in the 3D horizontal bar chart on figure 4 indicated that most researchers used quantitative research method in the reviewed period with 23 publications. Whereas two publications each used qualitative and mixed research methods in the reviewed period.

Table 4. Number of Publications per Research Methods

RESEARCH METHODS	NO. OF PUBLICATIONS
Qualitative	2
Quantitative	23
Mixed Method	2

**Figure 4. 3D Horizontal Bar chart Showing Number of Publications per Research Method**

4.4. Instrument for data Collection

Data collection instruments are tools used to collect facts by the researcher in a valid and reliable manner essential for decision-making in scientific investigations. Instrument for data collection allows researchers gather required information in a systematic and accurate manner critical for conducting scientific research. The bar-chart on figure 5 shows the instrument for data collections used by researchers in the year from 2018 to 2022. The bar-chart shows that most researchers used achievement test for data collection with 18 publications in the reviewed period. This is followed by questionnaires, which recorded seven publications in the reviewed period. The least popular data collection instrument in the reviewed period was interview with two publications. Other data collection instruments such as observation and diagnostic recorded five publications in the reviewed period.

Table 5. Number of Publications per Data Collection Instrument

| INSTRUMENTS	NO. OF PUBLICATIONS
Achievement Test	18
Questionnaire	7
Interview	2
Other Instruments	5
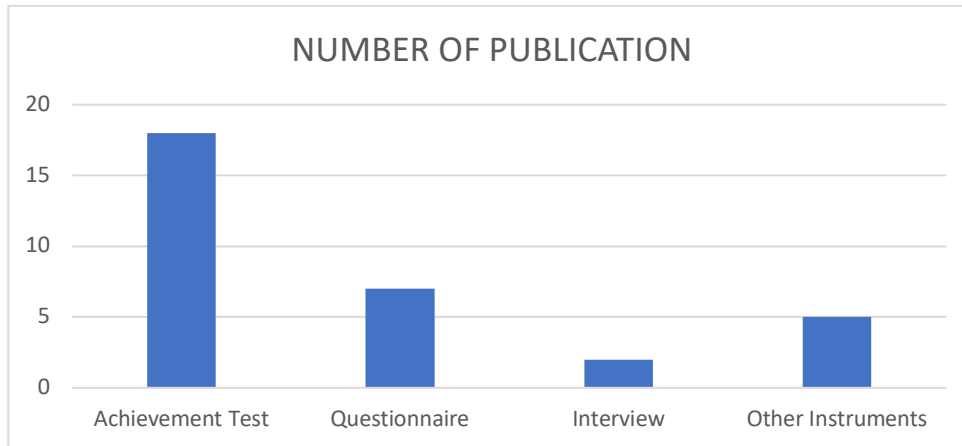
Figure 5. Bar chart indicating Number of Publications for Data Collection Instrument

4.5. Research Design Used

Research design refers to the overall strategy chosen by the researcher to ensure effective conduct of the study. It serve as the blueprint to guide the researcher in the collection, evaluation and analysis of data. The 2D horizontal bar-chart on figure 6 represent the number of research design used by CBS on learning outcome researchers in the period from 2018 to 2022. It can be clearly seen that most researchers used quasi-experimental research design with 23 publications in the reviewed period. Case study recorded the least with 1 publication in the reviewed period. Whereas survey recorded 3 publications in the reviewed period.

Table 6. Number of Publications per research Design

RESEARCH DESIGNS	NO. OF PUBLICATIONS
Case Study	1
Quasi-experimental	23
Survey	3
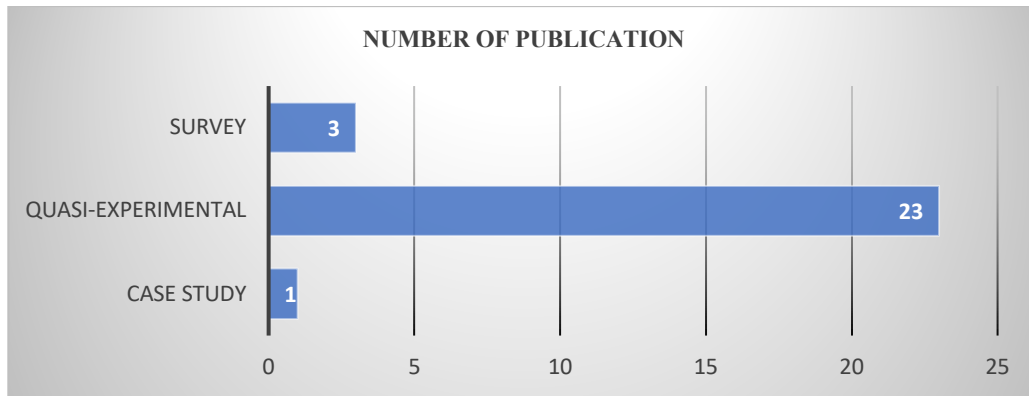
Figure 6. 2D Horizontal Bar chart indicating Number of Publications for Research Design

5. Conclusion

Computer-based simulation (CBS) in this context 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 versions 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. Studies have shown that the use of CBS enhances learning outcome in many subjects as shown in table 3. The recent trend in research on CBS in relation to teaching and learning shows that there is an increase in research on this topic in 2020. This might be connected with the emergency adoption of virtual instructions in the COVID-19 lockdown globally. It is recommended that CBS be utilize for instructions of complex scientific phenomenon to enhance learners' understanding of the difficult concepts. Furthermore, quasi-experimental is the popular research design and achievement test is the instrument for data collection used by most researchers in the reviewed period. Also, the author recommend quantitative research method for investigating the effect of CBS on learning outcome. Further research is recommended toward development and use of computer programs to simulate complex biological processes that cannot be observed in real life.

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