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Effect of crafted Bohr's atomic representation on students' academic performance in chemistry in Kayonza District, Rwanda

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Abstract

The study was to investigate the impact of using crafted Bohr's atomic representation as alternative chemistry resources on students' higher order thinking and their effect on student's academic performance. Using crafted Bohr's atomic representation as instructional resource, a student improves learning skills to correct concepts misconception. The study is a quasi-experimental with pre-test post-test, experimental and control group design and it is quantitative. With a sample of 330 students that was calculated from a population of 24,523 students at one of districts in Rwanda, the students were placed into two group using non-random sampling technique and each group composed of 165 students. Findings revealed a higher increase in experimental group's percent mean score than the control group's suggesting a positive impact on higher order thinking, and for that reason, students exposed to the instruction using crafted Bohr's atomic representation agreed at high level that exposure enhanced higher order thinking skill and positive interest in chemistry subject. It is suggested that crafted Bohr's atomic representation may are developed using resources found around the school, as they improve students' academic performance.

Keywords constructivism theory; crafted Bohr's atomic representation; chemistry instructional resources; students' academic performance

Introduction

Over time, Chemistry emerged as one of the scientific disciplines that took on its current systematic form in the 18th century, continuing into the late 19th century. Pioneers like Lavoisier, Proost, and Dalton methodically conducted quantitative experiments that led to pivotal discoveries such as the law of definite proportions, the law of conservation of mass, and the law of multiple proportions. These fundamental laws stemmed from Dalton's atomic theory of matter (Forrester, 2019). Thus, chemistry is an applied and empirical science where global academic investigation was conducted to develop and establish chemistry curricula, by examining the natural world to determine the validity of a hypothesis.

The educational philosophies for chemistry instruction espouse that "an accomplished educator must possess various instructional and knowledge-building tactics and instruments that can be utilized in the classroom to assist students in constructing

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knowledge (Ahmad, Ammar, Sellami, and Al-Thani, 2023). In light of the applied essence of Chemistry aligned with 21st century aptitudes, Rwanda developed a competence-based curriculum while outfitting chemistry labs with materials. However, in most Rwandan fundamental secondary institutions, these laboratory supplies were insufficient for supporting all hands-on chemistry activities (Nkurunziza et al, 2023). In 2019, MINEDUC's academic statistical yearbook denoted that only 26.6% of schools had a science laboratory, while the share of secondary institutions necessitating science kits was 63.8%, which remained inferior to the 2017/2018 Education Sector Strategic Plan (ESSP) goal of 90%. This signified that 73.4% of Rwandan schools still lacked laboratories to uphold all practical activities.

One solution to this obstacle was rallying Rwandan chemists, chemistry educators, and learners to invent and construct cost-effective materials as alternate pedagogical assets. Priority has been conferred on cultivating a systematic mindset among instructors and students, viable through hands-on coursework. The students must deem it critical to seek substantiation, garner tangibles, and fabricate discernment, impacting their scholarly undertakings.

In a scientific setting, science ought to differ from other liberal arts topics or languages in that merely lecturing on their content is not adequate teaching. Rather, active pedagogy and learning heightens students' understanding and memory, which assists them in develop problem-solving and critical thinking abilities at institutions of higher learning (Afzal Sayed Munna & Md Abul Kalam, 2021).

Then, in order for students to complete the "understanding" task, which is supported by laboratory equipment and learning materials that are discovered to be in limited supply in schools, they must be taught the difference between opinions and facts (Cossa & Uamusse, 2015). Thus, this study examined how students felt about using crafted Bohr's atomic representation resources as a substitute for traditional chemistry teaching resources and how it affected their academic performance in four schools chosen from the Kayonza district.

Because of this, chemistry education needs to be specifically planned to target higher order thinking and how scientists operate so that students may develop good ideas in a 21st-century learning environment. These are focused on experiential learning, where students in developed countries have significantly increased their scientific understanding, allowing them to utilize their material resources (Van Larr et al, 2020).

The attitude towards science in particular chemistry influenced student's academic performance. Various studies found that teaching students with activity-based learning approach, engage, keep motivation and excitement of students to learn chemistry (Umar Khitab, Zaman, Ghaffar and Jan, 2015; Ali & Papaiah, 2015; Hussain, Anwar & Majoka, 2011).

But it is difficult to teach chemistry in some schools of Rwanda, as laboratory materials are not enough in selected schools to develop scientific environment. This was supported in the research project of Khitab, Zaman, Ghaffar & Jan (2015) on impact of low-cost teaching material on students 'attitude towards science in Khyber Pakhtunkhwa Pakistan.

Therefore, it results in instructing chemistry using inexpensive materials as substitute educational resources to keep students engaged in relation to its impact on their scholarly achievement. Ultimately, in science education where a learner can comprehend their physical environment by cultivating a multicultural perspective of scientific occurrences, and affordable materials can facilitate the investigations.

Educational resources are vital and crucial pedagogical instruments required for instructing and acquiring knowledge of academic subjects to enhance students' scholarly achievement. They render learning more engaging, pragmatic, true-to-life, and appealing. They additionally enable both educators and learners to participate effectively and actively in classroom lessons (Olayinka, 2016). It is particularly thought of as solid as apparatus or organized liquid as chemical substance in which interactions between the entities forming the cluster that play significant roles in determining the resulting properties, for example the determination of isotopic properties (Berglund & Wieser, 2011).

As per the IUPAC technical report in 2009, material encompasses all apparatus and chemicals which are constituents of matter that exist in solid, liquid, and gaseous states.

In fact, recent research proved that eggshells contain 98 % of solid compound, that contain pure 94% calcium carbonate, 2% of water and the rest impurities are calcium phosphate and magnesium carbonate (Abeto & Bayu, 2020), whereas lemon juice was proved to contain citric acid (C6H8O7) with IUPAC name 2-hydroxy-propane-1,2,3- tricarboxylic acid and its pH range between 2 and 3 (Penniston, Nakada, Holmes, & Assimos, 2009).

Fascinatingly, the neutralization reaction between calcium carbonate in eggshells and citric acid was highly efficacious, whereas the atomic models that were designed pedagogically to symbolize atomic structure and delineate what constructive educators execute in their classroom to engage learners in reasonably endeavors. It aided the students to augment their social adaptability, personal aptitudes, cognitive abilities and behavioral aspect as well as facilitating the selection and stimulation of conditions that result in the desired transformations in students while demonstrating reactions of addition, combustion, combination, or synthesis.

This sustains educators' motivation and their elevated level of imparting instruction to the learners. This has been highly pivotal through an emerging pedagogical paradigm denominated the Self-Created Material Model (SMM), which entails students formulating their own low-cost material that augments students' academic achievement (Hertz, Clemson, Hansen, et. al., 2021; Méndez-Giménez, Carriedo, et. al., 2023).

The use of inexpensive materials in the current research exemplify the utilization of solid substances as discarded in the environment or procured from shops at a low cost, and materials as chemicals obtained and extracted from the surroundings of the school and individual person in the context of the teaching and learning process. Besides, a review of the senior two chemistry syllabus indicated that 80% of 10 units to be covered in the whole year can be taught using crafted Bohr’s atomic representation and specifically, this study focused on topic area of: chemical reaction, sub-topic area; types of reaction, which are also covered in the ordinary level chemistry syllabus (REB, 2015). The substance in this study was to scrutinize addition, combustion, combination or synthesis reaction, and neutralization in unit 5 of the chemistry syllabus. Specifically, the following research questions were formulated to guide the study:

1. How do crafted Bohr’s atomic representation impact the higher order thinking of students in chemistry subject?
2. What is the impact of using crafted Bohr’s atomic representation on

students 'academic performance in chemistry lessons?

In order to answer the research questions the following hypotheses were formulated:

H_{01}: Students taught chemical reactions using crafted Bohr's atomic representation will achieve higher academic performance in chemistry than their counterparts taught without the materials.

H_{02}: Students taught chemical reactions using crafted Bohr's atomic representation will demonstrate more higher thinking skills in chemistry lessons than their counterparts taught without the materials.

Theoretical framework

Constructivism theory of learning gives total opportunity and promotes the idea of the learner to create knowledge, deepen skills and meaning from their experience. Constructivism is rooted in the theory of Piaget (1970), who believed that students internally thinking about how the world intervene through natural science, learned experiences and observations. Constructivism's primary traits are (i) supporting students in creating knowledge; (ii) allowing for the development of information based on prior experiences; (iii) fostering social interaction; and (iv) transforming learning into realistic concepts for real-life situations (Tsulaia, 2023).

Therefore, it culminates in the augmentation of students' academic achievement as they comprehend the imparted instruction profoundly due to the utilization of apposite educational resources. The disposition towards chemistry may influence students' academic performance and accomplishments.

In that circumstance, the employment of inexpensive materials as instructional resources renders the students' creative thinkers, aligning with the primary objective of instructing chemistry, which ensures their enhanced academic achievement.

Literature review

Chemistry is one of the vital subjects of science, it has the ability to connect other sciences together and to encourage sizeable scientific literacy (Tera, 2018). Teaching and learning chemistry are facilitated by the use of instructional materials. However ,it was found in Rwandan Education statistical report of 2019 published by Ministry of Education that laboratory materials were not enough in all schools of Rwanda (MINEDUC, 2019).Some researchers like Ogwo(2014) stated that the basic tools that science uses in learning science process are instructional materials (Sivakumar, 2014). The instructional materials are used by teachers to increase the rate and the quality learning by students as well as making abstract expressions, concepts and generalizing more practical and become real (Englida, 2012). Therefore, it is in the context of learning that low-cost materials as instructional resources play a significant role towards the facilitation of students to create, innovate and construct new ideas in life for interpersonal and international development. This statement was supported by constructivism approach in which its ideas believe in students 'actively construct knowledge on their own, aided by appropriate instructional resources (Olusegun, 2015).

Constructivism theory of learning gives total opportunity and promotes the idea of the learner to create knowledge, deepen skills and meaning from their experience. Constructivism is rooted in the theory of Piaget (1970),who believed that students internally thinking about how the world intervene through natural science, learned experiences and observations (Piaget, 1970).

Consequently, result into the increase of students, academic performance as learners perfectly deeply understood the learnt instruction due to the use of appropriate instructional resources.

Attitude towards chemistry may affect students 'academic performance and achievements. In that case, the use of low-cost materials as instructional resources makes the students creative thinkers as the main goal of teaching chemistry which ensure their better academic performance. Therefore, attitude towards the use of crafted Bohr's atomic representation as alternative chemistry instructional resources are examined of students' attitude towards chemistry which was various researchers like (Archbong, 1997), (Hussian et al, 2011),reported that teaching chemistry with activity approach provides students with critical experience, and in science education, activity based teaching is focusing the creation of ideas and keep the students fully engaged in a practical work (Suydam et al, 1977).

Most science subjects, especially chemistry, are taught with activity-based approach, but it is difficult to meet students' academic performance where teaching materials are limited to develop scientific environment. Consequently, it is remarkable to teach chemistry using crafted Bohr's atomic representation in school laboratories where standard materials and chemicals are not enough to keep students on scientific track. Unfortunately, the impact on information processing and judgments were aspects of attitudes assessed in this study (Petty & Krosnick, 1995).

Petty (1995),further came to final definition of attitude as a consensus in which they are positive or negative thoughts, feelings or behaviour towards objects around us where as Simpson and Oliver (1990),believe attitudes as concept that gives emotional tendency relating events, scientific phenomenon or idea (Simpson & Oliver , 1990).Furthermore, attitude was viewed to consist of different sub-creative which ultimately give rise to individual's attitude towards science ,specifically chemistry (Osborn et al , 2003).It should be noted that role of science instruction is to strengthen and boost student's mastering of scientific ideas. Furthermore, it is generally recognized that students who received instruction that was actively focused on them as learners were better able to synthesize their information, exercise critical and creative thinking. This gave rise to higher learning achievement and academic performance. Furthermore, the traditional way of teaching chemistry theoretically has stimulated students to dislike studying chemistry hence lack of understanding the subject. On the other hand, chemistry is very important to science students and nation as it facilitates the creation of new ideas and innovation in nature. On such condition, the use of low-cost materials as chemistry instructional resources significantly improve student's interest in academic performance leading to improving their cognitive levels (Abubakar, 2023).

As the results obtained, proved that instructional resource is a device or object used by teachers to facilitate the teaching process in the classroom. These materials are so useful and significant to transfer knowledge from teachers to students to make them understand deeply the concept under investigation (Esiobu, 2005).

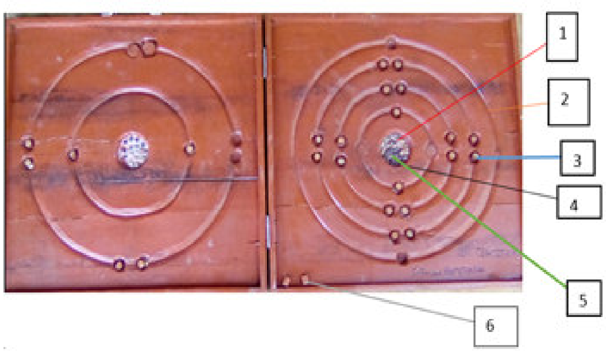
These materials include concrete and non-concrete, visuals and audial visual, fabricated models, chemistry kits, pictures, projectors and other materials from environment that can improve the teaching and learning. In particular, this study the teaching was conducted using fabricated atomic model adapted to chemistry curriculum and the use of this instructional resource made teaching and learning process easier, realistic, practical, and interesting.

This also created active participation of students during teaching and learning and improved knowledge, skills acquisition for students, leading their improvement in academic performance and confidence in subject matter (Eina & Ajayi, 2008; Denga, 2003).

Method

The study is a quasi-experimental with pre-test, post-test, experimental, control group design. The pre-test was used to test the previous knowledge of students used for study and post-test to measure their level of

Figure 1 Designed atomic model



Key to numbers in the model:

1. White small stones represent protons in the nucleus
2. Shell/energy level/orbital or principal quantum number(n)
3. Electrons in shells
4. Nucleus
5. Grey/black small stones reprsent neutrons
6. Un fixed electrons to be transferd during bonding.

achievements and academic performance. This study is quantitative research approach that was employed to test or measure reality examining the relationship among variables (Apuke, 2017).

It employs descriptive and inferential statistics in analyzing the data collected to answer first and second research questions which are deep-rooted in positivism that believes in doing things scientifically (Bloomfield & Fisher, 2019). These tools are most mean, standard deviation and correlation analysis as it has been favored in quantitative studies by Bloomfield and Fisher in 2019 for collected data when sample size is large (Seth Amoako & Ebenezer Boyah, 2023).

Different educational resources, like a teacher-made Bohr's atomic representation, empty water container, lemon fruits, blade, water, and eggshell were utilized to instruct student in the experimental group. While the control group received instruction through traditional teaching method without any teaching aids or instructional resources. The designed atomic model and chemical materials/apparatus are presented in Figures 1 and 2.

Figure 2 Chemical resources/apparatus

In the chemical resources/apparatus, the eggshells contain calcium carbonate and the lemon fruit contains citric acid; the knife was used to cut lemon juice, and the bottle was used in the preparation of lemon juice. The type of reaction between citric acid in lemon juice and calcium carbonate in eggshells is neutralisation reaction.

Initially, the material apparatus was an atomic model fashioned from wood, discarded empty water containers, and a home knife. And secondarily, the material chemicals were citric acid in lemon juice extracted from lemon fruits that were procured from home fruit trees and some from the marketplace or educational institution. Compounds for neutralization were reaction between citric acid and calcium carbonate that was obtained from discarded eggshells.

The sample was 330 senior two (2) secondary students from four (4) selected secondary schools in Kayonza under the status of public day and boarding schools. The grouping of students into experimental and control groups was done through non-random sampling technique which was based on one boarding and days school for experimental group of 165 students and the other one day and boarding schools for control group of 165 students.

This investigation was conducted during the second term of the 2022/2023 academic year for the experimental and control groups. The selection of six weeks allowed for standard instruction to cover 16 periods of Unit 5, classifications of chemical reactions. Each week encompassed 2 periods, spanning 80 minutes of teaching employing low-cost materials as chemistry instructional resources in the classroom for the experimental group, while the control group underwent a typical student-centered approach. Before the treatment, the subject both in experimental group and control were given a pre-test described in current revised Bloom's taxonomy of cognitive domain which classified intellectual behaviour into six levels of thinking in which the students 'academic performance was assessed and grouped into lower order thinking as remembering, understanding, and applying. Whereas higher order thinking level were analyzing, evaluating, creating, hence the cognitive domain facilitates educators to test higher order thinking of students during teaching and learning process (Théophile et al, 2022).

The tools employed for this study were chemistry assessment tests (CATs) for students to gauge cognitive disposition. The tests were used as both pre- and post-tests. To prevent the testing effect, certain numbering modifications were made on the test instrument to provide the appearance that the post-test was fundamentally different from the pre-test. The chemistry assessment test contained nine (9) questions, distributed in section A multiple choice with 10marks and open-ended questions section B 10 marks, and the paper was prepared with respect to cognitive Bloom's taxonomy levels that was revised in 2001.

Every correct option in section in each instrument scored 2 marks and wrong option scored zero or fail whereas the correct answer in section B in the instrument scored 1 or 2 marks based key concepts that were evaluated. The maximum marks for the whole items in the assessment test in each pre-test and post-test instrument were 20 marks. The test was found to have a Cronbach's Alpha value of .701 for its reliability.

Subsequently, after the learners had been instructed utilizing the low-cost materials (i.e., the teacher-made Bohr's atomic representation and the chemical materials/apparatus), the post chemistry assessment test was administered to them to evaluate their academic performance, particularly, their higher order thinking abilities with reference to Bloom's cognitive levels. Furthermore, higher-order thinking capacities are regarded as cognitive processes that aid an individual in linking information into a purposeful sequence of actions and utilizing those connections to resolve challenges (Afifah & RetWati, 2019), Distinctively, higher-order thinking encompasses both critical and imaginative reasoning, where creative thinking is a self-guided and self-regulated cognitive process that endeavors to rationalize at the utmost level of excellence in an impartial and equitable manner (Birgili, 2015).

Nevertheless, critical reasoning and ingenuity demand that students and teachers actively engage with the utilization of crafted Bohr's atomic representation, as they facilitate them in analyzing, assessing, and generating new concepts in the learning process, where analytical and evaluative orders of thinking suggest students' academic achievement while also fostering lifelong learners (Zin & Yu, 2023). The test group received treatment in the form of instruction using crafted Bohr's atomic representation as chemistry teaching aids, while the control group did not get treatment and received their regular science education. After the lesson was over, both the control and experimental groups took the post-test again.

The post-test for learners was employed to assess the academic achievement of the students and the extent to which higher order thinking in chemistry lessons was impacted by the utilization of low-cost materials in teaching and learning. In this scenario, the collected data were analyzed to indicate whether significant disparities existed between the pre-test and post-test scores as a consequence of the availability and use of low-cost materials in teaching and learning, thereby indicating the effect on scores and facilitating the answering of the first and second research questions.

This endeavor was undertaken to enable students to understand the effectiveness of utilizing low-cost materials in teaching and learning. However, more crucially for this study, the objective was to explore students' dispositions towards the use of low-cost materials and their ramifications on academic achievement in chemistry. In this regard, an achievement assessment, formulated based on Bloom's taxonomy, and was administered to students to gauge their higher order thinking capabilities and ascertain how the use of low-cost materials impacts their academic performance.

The gathered information was scrutinized at six cognitive levels to assess the degree to which the utilization of instructional materials in instruction enabled them to contemplate more profoundly, guiding them toward the generation of additional educational resources. Consequently, this investigation was undertaken to address the concerns reported by Okey, Ordu Kelechi, and Doris Omeodu (2018) in science education, wherein the number of students pursuing science has diminished in various nations globally, a phenomenon corroborated by the dearth of practical application, inadequate instructional resources (educational materials), drain teaching methodologies, and increase academic performance of students in scientific disciplines, particularly the subject of chemistry (Kelechi & Omeodu, 2018).

Ethical considerations, encompassing confidentiality, privacy, and the security of gathered data, were duly contemplated throughout the duration of this study. As the study was conducted within the confines of secondary educational institutions, ethical approval was formally solicited by means of an official written correspondence addressed to the Research and Innovation Unit of the University of Rwanda, College of Education, thereby permitting the researcher to proceed with data collection endeavors. The University of Rwanda-College of Education Research Screening and Ethics Clearance Committee (RSEC-C) provided its endorsement and recommendation for the undertaking of this study.

In addition, a letter was sent to the Kayonza District Authorities via the Education Office, which oversees secondary schools in responsibility, requesting authorization for this research in relation to the age-appropriate with consent form from research participants. The respondents were made aware that this study was being conducted solely for academic purposes.

It was made clear that participation would be entirely voluntary and that participants would always be free to decline or withdraw from the study at any moment. The study's respondents were not coerced into taking part. The decision to participate or not was made with the participants' informed consent. They were assured that a strict level of anonymity would safeguard their right to privacy.

The sample of filled research tools of data collected were kept safely and would not be published as the sample, only data (numbers and words) were analysed, discussed, and published and the interview was conducted in a place where the respondent would be free to respond to research question. The computerized data was protected by creating strong password to researcher's personal computer; therefore, nobody can have access to the research information

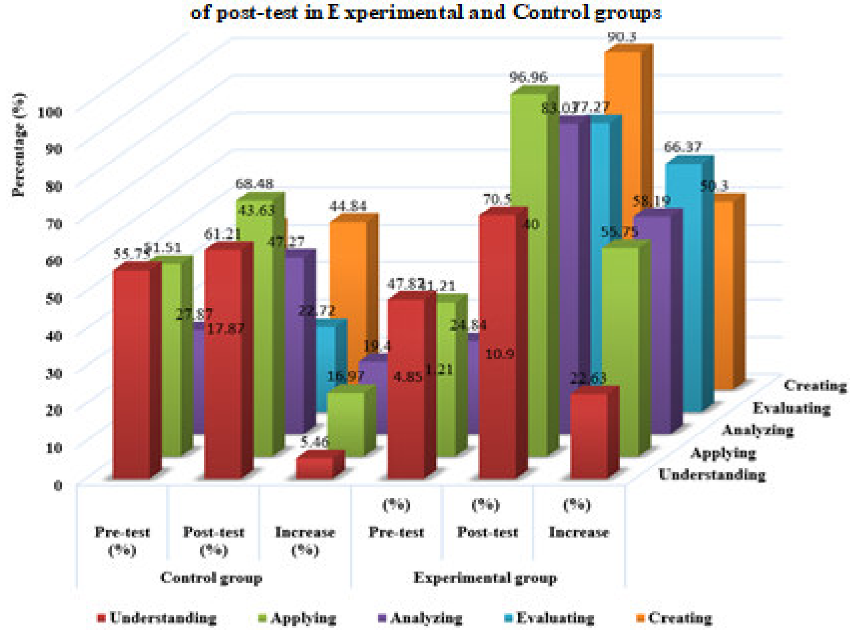
Using a quantitative research method, this study tested reality by studying the relationship between variables (Apuke O. D., 2017). It employs descriptive and inferential statistics in analyzing the data collected to answer the research questions which are deep-rooted in positivism that believes in doing things scientifically (Bloomfield & Fisher, 2019). These tools are most mean, standard deviation, regression with confidence level of 95% and correlation analysis as it has been favoured in quantitative studies by Bloomfield and Fisher in 2019 for collected data when sample size is large (Seth Amoako & Ebenezer Boyah, 2023). This part displays deeply the information collected from the respondents to answer the first and second research question.

Results and Discussion

How do crafted Bohr's atomic representation impact the cognitive thinking skills of students in chemistry subject? (Research question 1)

In the exploration of cognitive reasoning abilities, the higher order thinking faculties of students were quantified through the application of an assessment examination. The responses obtained from the participants evinced their capacity to undertake a critical analysis of the nature of chemical reactions exemplified by the model, encompassing combustion, synthesis, addition, and combination reactions, as elucidated by the equation below. The findings, consequent to analysis, were correspondingly presented in Figure 3.

Figure 1: Comparison of performance in percent between six cognitive levels of post-test in Experimental and Control groups



Scrutiny of experimental group, pre-test, and post-test

Figure 3 data displays the percentile achievements of students are becoming increasingly schematic to remembering. In other words, the amelioration is quite commendable, as evidenced by the gain percentage of 39. Cognizant of the fact that the increment stands at 23 percent, one is rendered more adept at discerning progress. The test results also reveal a gain of 56% in the application of skills, which constitutes a significant enhancement. Furthermore, the graphical representation demonstrated that students substantially increased their overall performance at the analytical level, with an increase of 58 percent.

Table 1 Comparison of standard deviation and mean of percent increase in six cognitive levels of posttest between Experimental and Control groups

Levels of thinking	Cognitive level	Experimental Group % increase	Control Group % increase	Cohen's D value
Lower order	Remembering	40	13	2.21
	Understanding	23	5	
	Applying	56	17	
Mean (M_1)		**39**	**12**	
Standard Deviation (SD_1)		**17**	**6**	
Higher order	Analyzing	58	19	5.62
	Evaluating	66	5	
	Creating	50	1	
Mean (M_2)		**58**	**8**	
Standard Deviation (SD_2)		**8**	**10**	

The assessment additionally discloses a 66 percent increase in cognitive altitude when it pertains to evaluating, but an expansion of 50 percent in performance capability when it relates to creating, which is likewise a substantial enhancement.

Consequently, the utilization of crafted Bohr's atomic representation educational resources where learners assemble various components to produce certain educational materials for the instruction process, construct models using mud and clay soil resulted in the escalation of higher cognitive levels. This elevated their degree of understanding and led to superior academic accomplishment than the control group, which received no intervention.

Scrutiny of control group, pre-test, and post-test

As a result, students in the control group made less progress in remembering, applying, and analyzing the knowledge presented in the above chart (13%, 17%, and 19%, respectively). On the other hand, students' performance declined to the percentages of 5.5, 4.9, and 1.2 in the cognitive domains of analyzing, assessing, and generating, respectively.

This provides credibility to the notion that student performance is undermotivated and ineffective at all six cognitive levels. The lower performance % suggests that students with less developed study skills who did not use cost-effective instructional materials performed worse. Table 1 provides a detailed comparison of the standard deviation and mean percent growth between the two groups.

Cohen's D value was calculated to measure the effect of crafted Bohr's atomic representation as alternative chemistry instructional resources on students 'academic performance using Lenhard & Lenhard's (2022) formula and the values obtained were used to measure the effect size of the change in performance (Liu & Chang, 2017).

The experimental group's mean and standard deviation of the percent increase in lower order thinking (M_1=39, SD_1=16.5) show that the students' scores in lower order thinking of cognitive levels were spread out the mean average, whereas the mean and standard deviation of the percent increase in higher order thinking showed that (M_2=58, SD_2=8.0).

The use of low-cost resources as alternative chemistry instructional resources has significantly impacted students' higher order thinking during the teaching and learning process, as indicated by the mean (M_2) of percent increase being higher and lower Standard deviation (SD_2) than in lower order thinking.

In contrast to the experimental group, the table showed that the control group's mean and standard deviation of the percent increase (M_1=11.92, SD_1=5.88) indicated a decrease in lower order thinking as well as a mean and standard of the percent rise in higher order thinking. The study's findings also showed that the mean percent rise in the experimental group and the control group differed statistically significantly. In particular, the control group's mean (M=8, SD=9.6) was lower than the experimental group's (M=58.3, SD=8.0), t(164) =1, p =.001.

The results showed that students in the experimental group exposed to instruction using low-cost materials as chemistry instructional resources performed better than their counterparts who did not receive the treatment.

The percent mean and standard deviation in six cognitive levels of Bloom's taxonomy for students taught using crafted Bohr's atomic representation as alternative chemistry instructional resources were studied in unit 5 of the content of ordinary level chemistry syllabus, and it was applied to senior two selected secondary schools of Kayonza district in Rwanda.

At a 95% confidence level, the differences between the two groups' higher order thinking findings in terms of percent mean and standard deviation were statistically significant at the 0.05 level of significance. The reason for the higher impact on higher order thinking skills in the chemistry assessment test could be that students who were taught using crafted Bohr's atomic representation as alternative chemistry resources were able to better understand the concepts being taught through visual means and thus were able to concretize them.

This finding is in line with a study conducted in private schools in Ankara, Turkey, to examine the impact of concrete models on the geometry achievement and attitude of eighth-grade students. The study discovered that students who were taught geometry using concrete models outperformed those who did not receive the same treatment (Bayran, 2005).

Additionally, I concurred with Hussain (1998), who carried out research to examine the use of low-cost resources (equipment, glassware, chemicals) in chemistry education at the secondary school level in Pakistan. She discovered that students who were taught chemistry using inexpensive materials developed new perspectives on the classroom and laboratory environments. Additionally, she discovered that cost-effective materials aid in the acquisition of new concepts and abilities as well as the advancement of ideas, which leads to the development of higher order thinking.

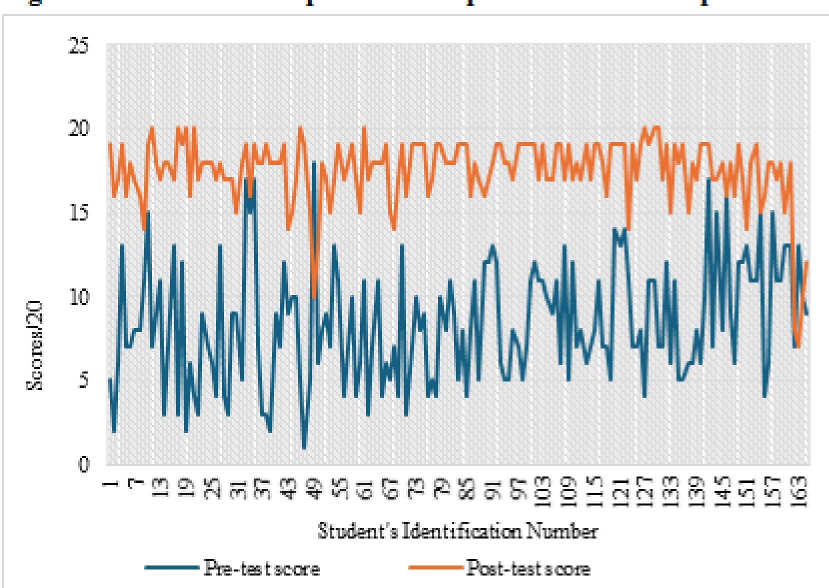
Cohen's d indicates that the effect size is d=5. 62, indicating a significant impact. Consequently, the higher mean percent increase in the experimental group indicates a bigger increase and favorable effect on students' higher order thinking as a result of employing inexpensive materials as substitute instructional resources for chemistry to improve teaching and learning.

Figure 4 is the line graph of the scores obtained by the experimental and control groups in the experiment. The figure reveals that students who used inexpensive study materials outperformed those who did not, indicating a larger influence of inexpensive resources as an alternative to chemistry. teaching and learning tool for the topic of chemistry.

The number of degrees of freedom t(164) in the table of t-value is significant at the 0.05 level and from the analysis point of view, the T-statistical calculated value (t=1) exceeds the given value for 0.05 level and 0.001 p-value as critical value at a confidence level of 95%. As a result, the null hypothesis($H0_1$)" *the use of low-cost materials has no impact on higher thinking of students in chemistry subject*" was rejected.

Furthermore, the second null hypothesis (H_{02}) was similarly disproved, stating that "*there is no significant effect of using low-cost materials on students' academic performance in chemistry*." The use of crafted Bohr's atomic representation had a considerable positive impact on students' academic performance generally, this was addressed the first research question of the study, and it was discovered that the experimental group's test results varied in a positive direction.

Figure 1 Test scores of pre-test and post-test for the experimental group



What is the impact of using crafted Bohr's atomic representation on students' academic performance in chemistry lessons? (Research Question 2)

To evaluate the impact of using crafted Bohr's atomic representation on students 'academic performance the difference between mean scores between pre-test post-test control and experimental groups are presented in the Table 2.

The utilization of teacher-made Bohr's atomic as alternative chemistry instructional resource has a significant influence, as measured by Cohen's d value of d=1.44. Given that Cohen's d value is more than 0.8, it is evident that instructional resources have a significant impact on students' performance (Cohen, 1988). The table also reveals the mean difference of -0.79 for the control group and a mean difference of -9.05 for experimental group between pre-test and post-test score.

Table 2 **Descriptive statistics of students' performance scores in the chemistry pretest and posttest in control and experimental groups**

Groups	N	Pre-test: Mean (M_1) and Standard Deviation (SD_1)		Post-test: Mean (M_2) and Standard Deviation (SD_2)		Mean difference (with in)
		M_1	SD_1	M_2	SD_2	
Control	165	10	4.9	11	3.4	-0.79
Experimental	165	8	8.6	17	2.1	-9.05
Mean difference		1.84		-6.42		8.26
Cohen's D value	165	0.18		1.44		

Table 2 displays the mean scores of students taught chemistry using crafted Bohr's atomic representation as alternative instructional resources and students taught using a learner-centered method without crafted Bohr's atomic representation. Additionally, the pre-test means and standard deviation for the experimental group (M_1=8, SD_1=8.6) and the control group (M_1=10, SD_1=4.9) are shown in the table. This demonstrates a 1.84 difference in the control group which is favored.

There are irrelevant variables that could be the cause of the two groups' different mean scores. Furthermore, this test's results show that the experimental group's mean pre-test score (M1, D1) is lower than that of the control group, with a statistically insignificant difference. According to Cohen's d value, the effect size is d=0.18, which indicates that while the mean score of students who took the post-test between the experimental (M_2, D_2) groups was significantly higher than the control group, the sample mean is roughly 0.19 lower than the population mean.

This shows that the experimental group's mean chemistry lesson scores increased more than the control group's after crafted Bohr's atomic representation were not used. On the other hand, it was observed that the experimental group's post-test means and standard deviation (M_2=17.46, SD_2=2.07) was higher than that of the control group (M_2=11.04, SD_2=3.41) by a difference mean of -6.42.

This means that the experimental group's lower standard deviation after instruction with crafted Bohr's atomic representation suggests that the students' scores are assembled around the mean and more consistent than those of the students taught without crafted Bohr's atomic representation. The result of the test of second hypothesis indicated that the difference in mean of students' academic performance in chemistry test as result of using crafted Bohr's atomic representation in teaching chemistry of the two group. This was statistically significant at 0.05 level of significance at confidence level of 95%. Such result may have made concepts more concrete being taught through their sense of sight and as such their better performance in chemistry assessment test.

This result support the findings of researchers like Okey et al (2018) (Okey, Ordu Kelechi & Doris Omeodu, 2018), who conducted a study to determine the effect of teaching organic chemistry using physical Model as instructional aid against teaching students' organic chemistry using diagrams as instructional aid in Obio/Akpor local Government area, River state. The study reported that students taught using physical instructional model performed better than the counterparts taught using diagrams as instructional aid.

Therefore, the difference in mean score and standard deviation of students taught chemistry using crafted Bohr's atomic representation as alternative chemistry instructional resources in senior two of selected schools of Kayonza district in Rwanda. The findings expressed that there was a significant difference in the mean score and standard deviation of students exhibited to instruction using crafted Bohr's atomic representation as alternative chemistry instructional resources showed a better students' academic performance than their parallel group of students taught without the treatment.

Conclusion

In examining students' attitudes towards the use of crafted Bohr's atomic representation and their effect on students' academic performance in Kayonza district, several key findings have emerged. The study revealed a diverse range of perspectives among students regarding the significance of learning materials and their associated costs. While some students expressed positive attitudes towards the utilization of crafted Bohr's atomic representation, others demonstrated reservations.

The data analysis demonstrated a correlation between students' attitudes towards learning materials and their academic performance. Students who exhibited positive attitudes towards the use of crafted Bohr's atomic representation tended to perform well academically, suggesting a potential link between resource perception, and learning outcomes. However, it is crucial to recognize the multifaceted nature of academic success, influenced by various factors beyond material resources.

Educational stakeholders in Kayonza district can leverage these findings to inform policies and practices. Initiatives aimed at promoting the use of affordable materials in classrooms may positively impact students' perceptions and, consequently, their academic performance. Additionally, targeted interventions to address the varying needs and preferences of students from diverse socio-economic backgrounds are crucial for fostering inclusivity and equitable educational opportunities.

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