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The Impact of an Educational Kit Based on a Virtual Laboratory in Chemistry for First-Year Middle School Students and Their Astute Thinking

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Abstracts

The present study investigates the influence of a virtual laboratory-based learning kit on the development of clever thinking skills among middle school students engaged in chemistry education. This research responds to the increasing demand for effective and engaging pedagogical approaches within the realm of science education. The study formulates a null hypothesis asserting that there is no statistically significant difference, at the 0.05 significance level, between the average scores of students in the experimental group utilizing the virtual laboratory-based learning kit and those in the control group receiving instruction through traditional methods. An experimental design with partial control was employed, featuring an experimental group comprising 34 students and a control group consisting of 32 students from Qadisiyah Middle School for Boys. Participants were randomly selected to create an unbiased sample of 66 students. The groups were equated based on key variables, such as age, grade 6 grade point average (GPA), and prior knowledge of the subject matter. To facilitate effective learning, twenty-four daily teaching plans were meticulously constructed: the experimental group's plans were aligned with the virtual laboratory-based educational kit, while the control group adhered to conventional instructional techniques. Subsequent statistical analysis was performed using SPSS to assess the outcomes of the two independent samples with unequal sizes. The findings revealed a significant enhancement in clever thinking skills among students in the experimental group who engaged with the virtual laboratory-based educational kit, in comparison to their counterparts in the control group. In conclusion, the results of this study indicate notable advantages associated with the incorporation of a virtual laboratory-based educational kit into chemistry instruction to foster the development of clever thinking skills among students. This research advocates for the integration of virtual laboratories into pedagogical practices and encourages further investigation across various educational levels and subjects to ascertain their broader implications for learning outcomes.

Keywords: Virtual Laboratory, Educational Kit, Clever Thinking Skills, Middle School Chemistry, Experimental Design.

Introduction

The need for innovative educational strategies in science education has become increasingly relevant in the contemporary learning environment. The integration of technology in education, particularly through virtual laboratories, has been recognized to enhance the learning experience and improve student outcomes. According to Al-Hafni (2000), "the effect" can be defined as the magnitude of change that occurs in the dependent variable after exposure to the independent variable (Al-Hafni, 2000: 21). This notion of effect is further emphasized by Shehata and Zainab (2003), who describe it as "the outcome of a desired, or desirable, change in the learner as a result of the process of education" (Shehata and Zainab, 2003: 22). In this study, the operational definition of effect refers specifically to the observable changes in the clever thinking skills of students in the experimental group after being exposed to the educational kit based on the virtual laboratory, as measured by post-test achievement scores.

The concept of an educational kit, often referred to as an educational bag, is vital for structuring learning experiences. Al-Huwaidi (2008) defines an educational bag as "a self-contained system that helps learners achieve educational goals according to the desired objectives" (Al-Huwaidi, 2008: 304). Similarly, Al-Heila (2016) characterizes it as "an educational unit of self-learning methods, which uses educational activities, and focuses on specific goals, to achieve educational outcomes measured by benchmark benchmarks" (Al-Heila, 2016: 220). For the purposes of this research, the educational kit is operationally defined as an integrated learning program comprised of various elements that collectively form an educational unit with a clear objective, addressing a specific topic or unit of educational material. This educational kit is distinguished by its unique characteristics, offering differentiated opportunities and a range of educational activities, supplemented by audiovisual materials, manuals, and evaluation tools.

Central to this research is the virtual laboratory, which serves as the technological foundation of the educational kit. Al-Hazmi (2010) defines a virtual laboratory as "an interactive learning and teaching environment that simulates a real laboratory, providing students with all the possibilities of laboratory tools, materials, and devices to conduct experiments independently or in groups, anywhere and anytime on a computer" (Al-Hazmi, 2010: 136). This definition highlights the convenience and accessibility of virtual laboratories, enabling students to perform experiments with safety and flexibility. Jagodzinski and Wolski (2015) further elaborate on the benefits of virtual laboratories, describing them as "computer-based educational software that allows the learning process to take place anywhere, at any time," thereby making abstract scientific concepts more comprehensible and encouraging effective student participation in experiments (Jagodzinski & Wolski, 2015: 16-28). In this study, the virtual laboratory is operationally defined as a computer-designed simulation of a real laboratory, featuring experiments aligned with the curriculum for first-grade middle school chemistry, expressed through both static images and animated drawings, using tools from the Crocodile program. Ultimately, this research seeks to assess the impact of an educational kit based on a virtual laboratory on the clever thinking skills of first-year middle school students studying chemistry, thereby contributing to the body of knowledge regarding the effectiveness of technologically enhanced learning environments.

The development of dexterous thinking, defined by Costa and Kallick (2000) as the inclination to engage in intelligent behaviors when confronted with problems lacking readily available solutions, is crucial in educational contexts. This type of thinking embodies a pattern of behavior that leads individuals to produce effective actions during cognitive dilemmas (Costa & Kallick, 2000: 2-3). Jarwan (2007) further emphasizes that dexterous thinking necessitates systematic, purposeful, and flexible approaches to problem-solving. In the current study, dexterous thinking is operationally defined as students' ability to respond to questions, assessed through scores on a specially designed dexterous thinking test comprising 14 traits, with each trait further divided into three paragraphs. Educational portfolios, integral to modern educational practices, emerged to accommodate diverse learner needs and facilitate individualized progress. These portfolios integrate various educational components aimed at achieving defined learning objectives, optimizing resource usage, and enhancing the effectiveness of teaching and learning processes (Tawalba et al., 2010: 231). They help students learn at their own pace, avoid comparative assessments that might discourage some, and allow teachers to diversify their instructional methods to ensure all students reach mastery (Sohail, 2012: 405). The theoretical framework of this research is grounded in constructivist theories of learning, which advocate for discovery-based learning environments. Within this framework, virtual laboratories serve as vital educational resources by enabling learners to interact with scientific concepts in meaningful ways. These environments help modify learners' pre-existing knowledge and encourage the integration of new information through exploration and active engagement (Abu Zant, 2015: 45). Virtual laboratories are particularly beneficial in teaching chemistry, as they facilitate the comprehension of abstract concepts that may prove challenging in traditional settings. They provide learners with realistic experiences that relate directly to their lives, thus fostering deeper understanding. The importance of virtual laboratories is underscored by their ability to offer flexible, safe, and cost-effective opportunities for scientific inquiry and experimentation. Notably, they enable students to perform experiments repetitively and at their own pace, delivering immediate feedback on their performance, which enhances learning outcomes and increases engagement (Rajwan et al., 2022: 219; Zeitoun, 2005: 165-166). Given the significance of dexterous thinking and the potential of virtual laboratories as educational tools, this study aims to explore the impact of an educational kit based on a virtual laboratory on first-year middle school students' dexterous thinking in chemistry, thereby contributing to the ongoing discourse on effective instructional strategies in science education.

Research Methodology

The researcher employed two types of research methods to achieve the objectives of the study: the descriptive research method and the experimental research method. These methods were utilized as follows:

1.1. Descriptive Research Approach

The researcher employed a descriptive research approach to construct an educational portfolio by analyzing its components and identifying distinctive characteristics. This methodological strategy encompassed several systematic steps, which are integral to developing a comprehensive and effective educational resource aimed at enhancing student learning outcomes. The first phase of this approach was the exploratory stage, which involved delineating the fundamental stages associated with constructing the educational portfolio. The researcher identified three primary phases: analysis, installation, and evaluation. Within each phase, a set of strategic steps was undertaken to ensure thoroughness and clarity in the portfolio's development.

During the analysis stage, specific information regarding the educational portfolio's casing was meticulously specified. The author of the portfolio, along with their supervisor, was noted beneath the title to provide appropriate attribution. Furthermore, the subject area of the portfolio was defined, focusing specifically on chemistry for first-grade intermediate students for the academic year 2023/2024. The target group was clearly identified as first-grade intermediate students enrolled in public schools during the same academic year, ensuring that the resource was tailored to meet the needs of its intended audience.

In addition, the objectives of the educational portfolio were determined to align with the overarching goals of enhancing student learning. The researcher articulated general objectives, which included developing student achievement levels in chemistry, accommodating individual differences among learners, and actively engaging students in the educational process. These objectives serve as guiding principles for the implementation of the educational portfolio, ensuring that it effectively addresses the diverse needs of students.

The characteristics of learners were also analyzed by the researcher through the use of an information card provided to participants in the study. The results of this analysis revealed important insights into the learner demographic. Notably, all learners belonged to the same age group, and the research sample demonstrated cultural uniformity at the family level. Furthermore, the intelligence levels between members of the experimental and control groups were found to be comparable, with no statistically significant differences identified. Additionally, all sample members experienced a similar learning environment, which likely contributed to the homogeneity of prior knowledge levels assessed among participants. The analysis also confirmed that the students' previous academic performance, as measured by sixth-grade primary school grades, exhibited no statistically significant differences among them, thereby affirming the suitability of the research sample for further investigation into the educational portfolio's impact.

1.2. Delimitations

The current research establishes clear delimitations to ensure a focused and manageable investigation. These criteria encompass spatial limits, time constraints, and specific academic content, which collectively frame the scope of the study.

Firstly, the spatial limits of the research are defined by its focus on first-grade students attending boys' intermediate schools governed by the Baghdad/Karkh Education Directorate. This geographic specification is critical as it contextualizes the educational environment and participant demographics for the academic year 2023–2024, allowing for targeted insights that reflect the unique settings of these schools.

Secondly, the research delineates time limits, restricting its activities to the first and second semesters of the academic year 2023–2024. This temporal focus ensures that the data collected and analyzed remain relevant to the instructional timeline associated with the educational interventions implemented during this specific period.

Lastly, the objective cognitive limits of the study concentrate on the content encompassed within four chapters of the chemistry textbook designated for the first intermediate grade. The sixth edition of this textbook (2023) serves as the core academic resource, and the selected chapters include: Chapter One, which discusses the Properties of Matter; Chapter Two, which delves into Atoms, Elements, and Compounds; Chapter Three, which covers the Composition and Classes of Substances; and Chapter Four, which focuses on Chemical Reactions and Their Expressions. By narrowing the study's content scope to these specific chapters, the research aims to provide detailed insights into the educational effectiveness and learning outcomes associated with the prescribed chemistry curriculum for first-grade intermediate students.

1.3. Analysis of Learners' Needs in Chemistry

The results presented in the table highlight the significant educational needs of first-grade chemistry students as assessed through the distribution of a questionnaire among 66 respondents, comprising both experimental and control groups. Most of the identified needs received chi-square values that exceeded the critical value of 5.991 at a 0.05 significance level with one degree of freedom, indicating statistical significance. Specifically, the needs for preparation before entering a lesson (N=45), diversification of teaching methods (N=51), the use of educational aids (N=60), conducting laboratory experiments (N=40), diversifying activities (N=49), utilizing diagrams (N=53), and linking knowledge to daily life (N=50) all showed strong support among students.

Notably, the students expressed the highest agreement regarding the necessity of using educational aids (60 students), along with a strong preference for daily assessments (64 students) and the application of technology in education (61 students). Conversely, the item regarding the need to diversify teaching methods also garnered significant agreement, further underlining the students' desire for varied instructional approaches. However, the need to diversify using fees (N=20) did not meet the threshold for significance, with a chi-square value of 0.364, indicating it was considered unnecessary by the respondents. This information was instrumental in helping the researcher address the educational needs when developing the educational portfolio.

In response to the identified needs, the researcher focused on identifying appropriate teaching strategies that would enhance learning outcomes in chemistry. These strategies included competitive discussions and collaborative learning approaches, which were subsequently reviewed and evaluated by subject matter experts to ensure their relevance and effectiveness in the classroom setting. Additionally, the researcher calculated the time required to implement the curriculum by determining the number of lectures necessary for comprehensive coverage of the material. It was concluded that a total of 24 classes would be required for both groups throughout the academic year of 2023/2024. This structural decision is essential for effective curriculum delivery and ensures that educators have adequate time to address the diverse needs of students as highlighted in the questionnaire.

The installation phase of the research project involved constructing relevant educational activities tailored to the chemistry curriculum. The researcher developed a variety of these activities, considering the specific needs and preferences expressed by the students. This approach not only fosters engagement but also aligns instructional methods with identified learning requirements, thereby facilitating improved understanding and retention of chemistry concepts among first-grade intermediate students.

Table 1: Analysis of Learners' Needs in Chemistry for First-Grade Students in both the experimental (N=34) and control group (N=32).

On	N	Yes	some time	No	Chi-square
1	The need to prepare to enter the lesson.	45	11	10	.091
2	The need to diversify teaching methods.	51	7	8	.364
3	The need to use educational aids.	60	6	0	273
4	The need to use the laboratory to conduct experiments.	40	18	8	.364
5	The need to diversify using activities.	49	6	11	.364
6	The need to diversify using fees	20	22	24	.364
7	The need to use diagrams.	53	8	5	727
8	The need for daily tests.	64	0	2	.364
9	Use of technology in education	61	3	2	727
10	The need to link knowledge to daily life	50	14	2	727

1.4. Educational activities

Table (2) presents a comprehensive overview of the educational activities organized for chemistry, categorized by different levels of study or stages of learning. The structure is divided into four primary categories, labeled as "suspensions," each representing a distinct focus or progression in the educational activities. These categories provide insight into the specific subjects addressed at each level, indicating the number of activities conducted for each subject under these categories. In the first suspension, there are a total of 15 activities distributed across three subjects. The first subject encompasses five activities, demonstrating a robust focus on foundational concepts, while the second subject has seven activities, suggesting that it may cover more complex topics or skills. The third subject features three activities, indicating a slightly lesser emphasis on this area, potentially reflecting its status as a supplementary topic within the broader curriculum.

The second suspension includes a total of eight activities that are also allocated across three subjects. Here, the first subject again shows some dedication with three activities, followed by the second subject with two activities, and the third subject with three activities. This distribution suggests a balanced engagement with various chemistry topics, ensuring a comprehensive educational experience. In the third suspension, the activities total seven, with each of the three subjects receiving focus. The first and second subjects each have two activities, while the third subject stands out with three activities, indicating a particular interest or necessity in that area. This suggests that learners at this stage are engaged with both fundamental and advanced chemistry concepts, promoting a deeper understanding of the subject.

Finally, the fourth suspension features a total of four activities spread across three subjects, with the first subject getting two activities, and the second and third subjects receiving one each. This diminishing number of activities might imply that the fourth suspension encompasses more specialized or advanced content, requiring less frequency in practice but emphasizing quality over quantity in educational engagement. Overall, the arrangement in Table (2) offers a clear picture of how educational activities in chemistry are structured across different learning stages, highlighting the focus and importance of each subject at various levels of chemistry education.

Table 2. Educational activities for chemistry

C	Suspension	Subject	Number of activities
1	The first	The first	5
		Second	7
		third	3
2	Second	The first	3
		Second	2
		third	3
3	third	The first	2
		Second	2
		third	3
4	Fourth	The first	2
		Second	1
		third	1

1.5. Preparation of Teaching Aids and Research Methodology

The researcher undertook several preparatory steps essential for the successful implementation of the educational program. This included the preparation of necessary teaching aids, which encompassed a range of materials such as chemistry illustrations, models, a blackboard, chalk, and a data projector. The incorporation of these tools was aimed at enhancing the learning experience and facilitating effective instruction in chemistry. In addition to preparing teaching aids, the researcher successfully set up a virtual laboratory on the students' electronic devices. This involved installing the necessary software, activating access codes, and providing comprehensive instructions on how to utilize the virtual laboratory effectively. The use of a virtual laboratory is expected to enrich the educational environment and offer students hands-on experience in performing experiments.

Furthermore, the researcher developed a pre-test comprising ten multiple-choice questions designed to assess students' prior knowledge. This pre-test was submitted to subject matter experts for validation to ensure its relevance and appropriateness for the intended evaluation. Such validation is crucial, as it confirms that the assessment aligns with the educational objectives and accurately measures the knowledge and skills of the students. To monitor student understanding throughout the instructional process, formative tests were also designed by the researcher. These assessments consist of short, exploratory questions that are administered at the conclusion of each lesson, enabling the students and instructors to gauge comprehension and identify areas needing further clarification.

The evaluation phase of the research involved the implementation of three types of evaluation strategies, aimed at adjusting student learning and assessing the overall effectiveness of the educational interventions. The researcher adopted an experimental research method, which is defined as a systematic approach to gathering information and data regarding a phenomenon following the introduction of a specific intervention intended to bring about change (Hassan, 2008: 246). For this study, a partially controlled experimental research design was employed, organized into clear steps to ensure rigorous methodology.

The research population comprised all first-year intermediate students enrolled in government schools within the Baghdad Governorate, specifically those under the Directorate of Education (Karkh I) for the academic year 2023–2024. A representative sample for the study was selected from this population, reflecting its inherent characteristics. It is pertinent to note that in experimental research, the selection of the sample involves various methods, with random selection being a fundamental requirement (Omar et al., 2009: 111). For the current study, a simple random sampling method was utilized, resulting in the selection of the Qadisiyah Intermediate School for Boys as the research sample. Both the experimental and control groups were derived from this selected institution, ensuring a well-structured and unbiased representation for the research findings.

Table 3. The research sample.

School Name	First Intermediate A	First Intermediate B	First Intermediate C	Total
Al-Qadisiyah Intermediate School for Boys	34	30	32	96

The paper clipping method was employed in this research to effectively analyze the subject matter at hand. Within this approach, Division A was specifically selected to serve as the experimental group, allowing for targeted observation of the effects being tested. In contrast, Division C was designated as the control group, providing a baseline for comparison. This division of participants is crucial for assessing the impact of the experimental conditions implemented in Division A while ensuring that any observed changes can be attributed directly to the interventions applied rather than external influences. The experimental design of the research forms a vital conceptual framework that underpins the entire study. This framework guides researchers in systematically collecting pertinent information and data needed to draw valid conclusions about the hypotheses set forth. According to Al-Qawasmeh et al. (2012), the experimental design provides both structure and direction, ensuring that the research objectives are met through methodical execution. The outlined experimental design, as displayed in the subsequent table, illustrates the specific parameters, methodologies, and categorizations of data utilized in this study. By adhering to a well-defined experimental design, researchers can maintain rigor and reliability, ultimately enhancing the credibility of their findings.

Table (4) outlines the experimental design of the research by categorizing the participants into two distinct groups: the experimental group and the control group. This design is instrumental in determining the effectiveness of varied instructional methods on students' learning outcomes. The experimental group is exposed to the "Learning Portfolio" treatment. This approach typically involves an educational strategy that emphasizes the use of portfolios as a tool for students to compile and reflect on their work, thereby enhancing their learning experience. The learning portfolio is designed to promote active engagement with the material, encourage self-assessment, and facilitate deeper understanding through the organization and synthesis of information. As part of the evaluation for this group, participants take the "Dexterous Reasoning Test." This assessment aims to measure their deft thinking and reasoning skills in a structured format that aligns with the objectives of the learning portfolio treatment.

On the other hand, the control group experiences "the usual way," which likely refers to conventional teaching methods typically employed in the educational context. This may include traditional lectures, textbook-based learning, and standardized assessments that do not incorporate interactive or reflective elements like the learning portfolio. Although this method has its merits, it may not engage students as effectively or foster the same level of reasoning skills as the educational portfolio approach. By comparing the results of Quiz 1 between the experimental group, which utilized the learning portfolio, and the control group, which followed the usual teaching method, the research aims to evaluate the impact of the innovative instructional strategy on students' ability to reason dexterously. The findings can provide valuable insights into the effectiveness of different teaching methodologies in enhancing students' cognitive skills in chemistry or other subjects.

Table 4. Experimental design of the research.

Group	Treatment	Quiz 1
Experimental group	Learning Portfolio	Dexterous Reasoning Test
Control group	The usual way	

Table 5 presents the equivalence of two research groups concerning various variables critical to the study. This table is structured to compare the experimental group and the control group across four specific parameters: chronological age, prior information, a variable denoted as "What? Row F?," and the Pre-Skilful Thinking Test scores. Each row includes the number of participants, mean values, standard deviations (SD), degrees of freedom (df), calculated T-values, tabular T-values, and whether the results are statistically significant. Starting with the chronological age, the experimental group, which consists of 34 participants, has a mean age of 149.319 years, while the control group, comprising 32 participants, has a mean age of 150.727 years. The calculated T-values for both groups are 1.066 and 0.581 respectively, against a tabular T-value of 1.98. Since the significance results are noted as "Not significant," it indicates that there is no statistically significant difference in chronological age between the two groups, suggesting that both groups are comparable concerning age and therefore can appropriately participate in the study.

Next, regarding prior information, the experimental group has a mean of 10.59 with an SD of 4.18, and the control group has a mean of 11.25 with an SD of 3.39. The T-values for the experimental and control groups are 1.584 and 1.508, respectively, which do not exceed the tabular value of 1.98. Again, the results are classified as "Not significant," indicating that there is no significant difference in prior knowledge between the groups, reinforcing the concept that both groups come to the study with similar backgrounds in knowledge. The variable labeled **"What? Row F?" shows a mean of 18.61 (SD = 6.7) for the experimental group and a mean of 63.53 (SD = 4.53) for the control group. The calculated T-values (1.654 and 1.840) remain below the tabular T-value of 1.98. The designation of "Not significant" implies that the differences observed in this measure do not reach statistical significance; hence, it reinforces the equivalency between both groups regarding this specific variable. Finally, the results for the Pre-Skilful Thinking Test indicate that the experimental group scored a mean of 84 (SD = 2.376), while the control group scored a mean of 83.78 (SD = 2.96). The T-values (0.709 and 0.760) indicate no statistically significant difference when compared to the tabular T-value of 1.98, further confirming that both groups do not differ significantly regarding their pre-skilful thinking abilities. Overall, the results presented in Table 5 illustrate that both research groups are equivalent across the evaluated variables, affirming that any differences observed in subsequent analyses can reasonably be attributed to the treatments they received rather than pre-existing disparities in age, prior knowledge, or cognitive skills. This equivalence is crucial for the validity of the research findings, as it helps to isolate the effects of the experimental treatment from other extraneous variables.

Table 5. Equivalence of the two research groups

Variables	Group	Number	mean	SD	df	T value		S.g.
						Calculated	tabular	
Chronological Age	Experimental group	34	149	319	64	1.066	1.98	Not significant
	Control group	32	150	727	64	0.581	1.98	Not significant
Prior information	Experimental group	34	10.59	418	64	1.584	1.98	Not significant
	Control group	32	11.25	839	64	1.508	1.98	Not significant
What? Row F?	Experimental group	34	18.61	6.7	64	1.654	1.98	Not significant
	Control group	32	63.53	453	64	1.840	1.98	Not significant
Pre-Skilful Thinking Test	Experimental group	34	84	2.376	64	0.709	1.98	Not significant
		32	83.78	296	64	0.76	1.98	

Statistical Analysis: The researchers employed the Statistical Package for Social Sciences (SPSS) to analyze the data and derive conclusions.

Result

The hypothesis stated that "there is no statistically significant difference at the 0.05 level between the mean scores of the experimental group students, who learn using a virtual laboratory-based learning portfolio, and the mean scores of the control group students, who learn through the conventional method of studying chemistry." To test this hypothesis, the researcher used an independent samples t-test to identify differences between the mean scores of the experimental and control groups on the achievement test. The results are presented in the following table:

Table (5) Differences in the level of deft thinking between the experimental and control groups.

Group	Sample size	Mean	Standard deviation	Degree of Freedom	T value		Sig
					Calculated	tabular	
Experimental group	34	85.71	3 139	64	839	1.98	Significant
Control group	32	77-94%	788				

The results indicated in the table above reveal statistically significant differences at the 0.05 level of significance regarding the levels of deft thinking in chemistry among students. These findings affirm the hypothesis that the experimental group, which engaged with the educational portfolio, significantly outperformed the control group that followed conventional teaching methods. This disparity in performance can be attributed to several key factors that underscore the advantages offered by the educational portfolio approach.

One significant factor is the effectiveness of the educational portfolio in reinforcing information through repetition, which enhances memorization and solidifies knowledge retention among students. The structured nature of the educational activities and the experiments included in the portfolio facilitated continual engagement with the material, ensuring that students could revisit and internalize concepts thoroughly. Such repetition is crucial in chemistry, where foundational knowledge is essential for understanding more complex topics.

Furthermore, the handling of information within equations in the educational portfolio was designed to enhance comprehension among students. The integration of a virtual laboratory experience complemented this understanding, as it provided a hands-on approach that stimulated interest and engagement. Active classroom participation was also instrumental in promoting deeper comprehension, as students could collaboratively grapple with and discuss challenging concepts within the material. Moreover, the organization of knowledge and concepts within the educational portfolio allowed students to analyze and synthesize information according to developed cognitive schemes. The pedagogical strategy employed moved from a holistic overview of concepts to a detailed exploration of their components. This scaffolded approach not only clarified complex relationships among ideas but also empowered students to break down the material systematically, thereby enhancing their analytical skills in chemistry.

Considering these findings, several recommendations can be proposed. Firstly, it is essential to provide robust training for teachers on how to design and effectively implement educational portfolios, given their demonstrated capability to boost students’ academic performance. Secondly, there is a pressing need to integrate virtual laboratories into chemistry curricula, especially to mitigate the limitations posed by a lack of physical laboratory facilities in public schools. This integration will not only enrich students’ learning experiences but also minimize the risks associated with traditional chemical experiments. Additionally, educators are encouraged to diversify their teaching methodologies in chemistry instruction. Utilizing a range of instructional strategies can significantly augment students' comprehension and mastery of scientific concepts, ultimately resulting in more effective learning experiences.

Based on the outcomes of this research, the researcher proposes further investigations to bolster the academic landscape. Such studies could encompass the application of virtual laboratories across various subjects, therefore expanding the benefits observed in this experiment. Moreover, conducting experimental studies that evaluate the impact of educational portfolios on higher-order thinking skills could provide valuable insights into their broader educational effectiveness. Finally, applying similar experimental designs at different educational levels would help assess the generalizability of these findings and contribute to the ongoing evolution of teaching methodologies in science education.

Discussion

The results indicate that there is a statistically significant difference between the mean scores of the experimental and control groups, confirming the hypothesis that students who utilized a virtual laboratory-based learning portfolio performed better than those taught through conventional methods. The experimental group's mean score of 85.71, in contrast to the control group's mean score of 77.94, highlights the effectiveness of innovative instructional strategies in enhancing student outcomes in chemistry. One possible explanation for the superior performance of the experimental group lies in the educational portfolio's capacity to reinforce knowledge retention through repetition. This finding aligns with the work of Al-Haila (2016), who emphasized the importance of structured learning experiences in fostering deeper understanding. The design of the educational portfolio facilitated ongoing engagement with content, allowing students to revisit and internalize complex concepts. Such continual interaction is crucial in subjects like chemistry, where foundational knowledge is integral to mastering intricate topics and facilitating higher-order thinking (Rajwan et al., 2022). Additionally, the integration of a virtual laboratory provided students with hands-on experiences that significantly enhanced their comprehension and engagement. This interactive approach, as discussed by Abu Zant (2015), not only stimulates interest but also allows students to experiment with concepts in a supportive environment, thereby promoting active learning. Classroom participation further augmented this exploratory process, fostering collaborative discussions that deepened understanding and encouraged students to tackle challenging concepts collectively (Suhail, 2012). The organized structure of the educational portfolio also enabled students to approach complex information more systematically. By breaking down intricate relationships within chemistry content, students could analyze and synthesize knowledge more effectively. Tawalba et al. (2010) argue that scaffolded learning experiences, like those afforded by educational portfolios, contribute to the development of students' analytical skills, which are crucial for success in scientific disciplines.

Conclusion

In conclusion, the adoption of a virtual laboratory-based learning portfolio has demonstrated a significant positive impact on the deft thinking abilities of students in chemistry, compared to traditional teaching methods. The findings underscore the potential benefits of integrating educational portfolios and virtual laboratories into the science curriculum. Recommendations based on this study suggest that teacher training programs should emphasize effective portfolio design and implementation strategies to enhance educational delivery. Moreover, the integration of virtual laboratories into curricula can address the limitations posed by physical lab resources, while also ensuring the safety of students during chemical experimentation. By diversifying instructional methodologies, educators can enrich student comprehension and mastery of scientific concepts, ultimately leading to more effective learning experiences. Future research should explore the implementation of virtual laboratories across various subjects to identify further benefits and extend the positive outcomes observed in this study. Additionally, examining the impact of educational portfolios on higher-order thinking skills can provide insights into their broader educational effectiveness. Finally, applying similar experimental designs across different educational levels could contribute to the ongoing evolution of teaching methodologies in science education and facilitate a more comprehensive understanding of skills development in various academic contexts.

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