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Effectiveness of Hands-on Learning (HoL) as Instructional Strategy for Teaching Primary Science

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Abstract

This study evaluates effectiveness of Hands-on Learning (HoL) as an instructional approach for teaching science in sixth-grade students at in a Primary School, Wangdue Phodrang. The study employed an experimental design comparing the learning scores of students in an experimental group (EG) exposed to HoL and a control group (CG) receiving traditional instruction. Academic test scores of 42 participants were gathered using pre-tests and post-tests and analyzed using descriptive and inferential statistics, including paired-sample t-tests, independent-samples t-tests, and correlation analysis. The findings reveal participants in the experimental group, taught with HoL, demonstrated a significantly ($p<0.05$, Cohen's d= 1.23) higher mean increase in academic achievement. The study also indicates that participants' gender and interest on the subjects impacts the implementation of HoL. Correlation analysis revealed positive relationships *(Pearson's r = 0.47)* between pre-test and post-test scores, indicating consistent improvement across both groups. This research contributes to the understanding of effectiveness of the HoL and factors which impacts its implementation in teaching the science concepts in Bhutanese classroom.

Keywords: Hands- on learning, science teaching, instructional strategies, academic achievement.

Background

The Educational Reform's Royal Decree, dated 17th December 2020, stipulates the inclusion of science, technology, engineering, and mathematics (STEM) in the regular discourse (Kuensel, 2021). These directives highlight the importance of STEM and ways to equip the present Bhutanese student generation for the challenges of the forthcoming global landscape. Following the Royal Decree, the process of science teaching-learning has undergone numerous changes in both content and pedagogical shifts. According to the Department of Curriculum and Professional Development [DCDP] (2022), the science curriculum's content shifted its focus from 'learning what' to 'learning how and why'. With the paradigm shift, science education has witnessed an emerging emphasis on innovative instructional approaches which foster active engagement and meaningful learning experiences for the learner. One such approach is hands-on learning, which has direct interaction with the real-world materials, objects, or situations in terms of students' conceptual learning.

However, several studies have revealed that Bhutanese classrooms still rely on transmissive teaching approaches, where teachers dominate and learning is limited to a few textbook-based activities (Gyamtso & Maxwell, 2012; Mongar, 2022; Sherab & Dorji, 2013). Further, Bhutan PISA-D report (2019) emphasized that schools should ensure adequate laboratory materials in addition to well-structured laboratory activities to provide hands-on activities and experience to students to promote scientific literacy domains. Thus, it signals strong indication that teachers rarely use hands-on learning for teaching science for better academic performance. Therefore, such inconsistences have prompted the researcher to explore the effectiveness of the hands-on learning strategies in teaching science. The study was guided by a central question and two sub-questions.

Central Research Question

In what ways does hands-on learning enhance the teaching of science for grade six students?

Sub-questions:

1. How does academic achievement differ between students taught through hands-on learning and those taught using traditional methods?
2. What are the factors affecting the implementation of hands-on learning as instructional strategies in primary science?

Aim and Objectives of the Study

The general aim of the study is to examine the effectiveness of the hands-on learning as instructional strategy to bring better academic performance science in grade six. Some of the objectives for the study are:

i. Examine the relationship between hands-on activity and students' learning scores.

ii. Identify the factors that affect the implementation of hands-on activity as an instructional strategy.

Literature Review

Globally, the goal of science education is to build scientifically literate individuals for a better world. Science education plays a crucial role in creating scientifically literate graduates who are equipped with the knowledge and skills necessary to contribute to a better world (Fuchs & Tan, 2022). Trends in International Mathematics and Science Study (TIMSS) reported that the aims of science teaching is for skills development for working scientifically, designing and becoming constructivist (Mullis et al., 2012). According to the Department of Curriculum and Professional Development (2022), science education aims to equip young minds with the scientific knowledge and skills to make educated decisions in their everyday life. Therefore, science education creates graduates with scientific literacy and skills for making the better world.

The achievement of the goal of science depends on how science is being taught in the school. Several studies revealed that confined classroom teaching and learning still dominate science teaching which deprives skill acquisition, needed in fast-changing world (Felder, 2021; Visco Jr, 2017; Zhao, 2015). In contrast, the learner-centered teaching pedagogies such as inquiry learning, experiential learning, hands and minds-learning, and discovery learning are found to bring positive learning scores and attitudes toward STEM learning (Alkan, 2016; Ateş & Eryilmaz, 2011; Resmawati et al., 2018; Satterthwait, 2010; Weinberg et al., 2011). Therefore, it is asserted that a more relevant learner-centered instructional strategies such as hands-on learning (HoL) be implemented to achieve the goals of science education as it develops positive learning attitude and skills.

HoL allows students to engage with scientific concepts through direct observation and experimentation, which can increase their understanding, curiosity, enhance students' learning engagement, and promote the development of 21st century skills (DCPD, 2022; Kibga et al., 2021). Moreover, it is reported that students learn deeply when engaged in learning by doing (Stull & Mayer, 2007; Triona & Klahr, 2007). Thus, HoL can be effective in teaching primary science.

Understanding HoL

According to Satterthwait (2010), HoL is defined as a teaching strategy in which the learners work in groups, interact with peers to manipulate, ask questions with observation, collect data and learn. Flick (1993) stated that it as a specific instructional strategy where learners are actively engaged in manipulating materials. To some, HoL generally means learning by experience (Holstermann et al., 2009). Nekhely and Eassa (2021) also defined HoL as learning by doing where learning can transform the abstract into concrete through manipulation of objects, tools and materials. According to the DCPD (2020), HoL is synonymously used as hands-on experiences. It involves practice, learning, and carrying out tasks that involves the learner with real object and situation. Thus, HoL is a strategy which enables learning to learn concepts with the use of manipulative objects and materials. The similarity among the definitions provided in studies are HoL as a teaching strategy engaging with manipulating materials, building experiences and using real objects. It is evident from the above similarities that HoL is an instructional strategy where teachers plan and design their lesson which enable learners to learn by doing.

Effectiveness of Hands-On Learning

Global Context

HoL enables critical thinking, enhances motivation and learner's interest, and is used as an instructional strategy. According to Poudel et al. (2005), engaging in hands-on activities boosts students' confidence and motivates them to acquire the technical skills and enhances critical thinking necessary for comprehending problems and their potential solutions. Additionally, HoL enhances student's interest in learning the subjects. An experimental study conducted by Logar and Savec (2011) with 106 participants examined students' hands-on experimental work versus lecture demonstrations in teaching elementary school chemistry and found that hands-on activities had a significant impact on students' interest in learning chemistry. Furthermore, a study by Weinberg et al. (2011) involving 336 participants concluded that students develop interest in subjects and a willingness to persist in continued learning.

Further, Weinberg et al's (2011) study with 336 participants concluded that students develop interest in subjects and persistence for continue learning. Hands-on learning allows students to engage with scientific concepts through direct observation and experimentation, which can increase their understanding, curiosity, enhance student's learning engagement and promote the development of 21st century skills (DCPD, 2022; Kibga et al., 2021).Thus, HoL in the classroom is effective in fostering students' interest, persistence in learning, and enhancing motivation, which ultimately impacts science learning

Moreover, hands-on learning boosts the students' academic performance. A quasi-experimental study by Ateş and Eryilmaz (2011) on effectiveness of hands on and minds-on activities with 130 students of ninth grade found significant difference on students' achievement. Moreover, another quasi-experiment on effects of hands-on activity enriched instruction on students' achievement and attitudes towards science by Sadi and Cakirogulu (2011) with 140 participants also found a similar result. Su and Chen's (2023) study with 150 students also reported that HoL brings a positive impact to learning outcomes. Further, Fakaruddin et al.'s (2023) qualitative study with the six fifth grade students mentioned that HoL is beneficial in enhancing creative thinking in students, which enhances students' ability to understand the abstract concepts. Additionally, Resmawati et al., (2018) concluded that the students' learning outcomes in all cognitive, affective, and psychomotor aspects tend to improve while using discovery learning with experiments. Similarly, it is reported that students learn deeply when engaged in learning by doing (Stull & Mayer, 2007; Triona & Klahr, 2007). Based on their findings, HoL can help students to understand the scientific concept and improve their academic performance.

In contrast to benefits of HoL, these strategies in science education have some drawbacks. Ekwueme and Meremikwu (2010) reported cons of hands-on learning such as time-consuming nature and their potential to impede syllabus coverage. Moreover, Logar and Save (2011) found that students' content knowledge gained and knowledge retention is better in teacher's demonstration than the hands-on learning. As a result, the use of HoL science education may have certain limitations, potentially hindering its ability to consistently foster comprehensive learning experiences.

Bhutanese Context

This review of literature on Bhutanese science education revealed that students chose gamified learning environment over traditional method (Pelden et al., 2022). The research further revealed that they chose cooperative learning environment (Rabgay, 2018), blended approach of teaching (Wangmo, 2021), place-based education (Dorji et al., 2021) and learning styles (Wangdi et al., 2020). The research also focused on Bhutanese science teachers' perceptions on nature of science (Dorji et al., 2022), effects of using inquiry-based learning pedagogy in teaching science (Subba et al., 2019) and use of project-based learning approach in teaching science (Dorji, 2019). While these studies appear to have focused on various aspects of the subject but none of study thoroughly examined the impact of hands-on learning on students' academic performance.

Additionally, a few of studies specifically mentions the lack of HoL or limited deployment in the Bhutanese classroom. Number of studies revealed that Bhutanese classrooms use transmissive approaches where teachers dominate with few textbook-based activities (Gyamtso & Maxwell, 2012; Mongar, 2022; Sherab & Dorji, 2013). Similarly, Mongar's study on Bhutanese teachers' and students' perspectives on approaches to teaching ESD through environmental science also found limited usage of hands-on activities, experiments, fieldworks and exhibitions in the lesson (2022).

In contrast, DCPD (2022) mentioned that hands-on activities, laboratory investigation, fieldwork and project-based learning are some main strategies that can be used to teach science education. Therefore, the studies show that science teaching in Bhutanese classroom are more transmissive approaches (teacher centered) with limited use of HoL.

Nevertheless, a few studies in Bhutan have revealed that the HoL can excite students, spark their interest and increase engagement in the lesson. First, the study by Tharchen et al. (2022) involving 320 participants on factors hindering conduct of biology laboratory work in classes IX and X schools under Trongsa district found that HoL (practical works) increased the student's engagement.

Secondly, Rai's (2021) qualitative study on "Pedagogical practices: Triggering and sustaining students' interest and engagement in Bhutanese science lessons" revealed that students displayed a highly favorable attitude towards engaging in learning with HoL and practical work. In addition, another study by Dorji et al. (2021) also observed that HoL embedded in place-based lessons enhances engaging, stimulating, and educative experiences for children. But these studies merely reported engagement and interest effects of HoL in the science lessons. In other words, none of the studies delved into the effectiveness of the HoL in enhancing the academic performance of primary school students, specifically in the context of teaching grade six science in Bhutanese context.

Internationally, the previous studies on effectiveness of HoL in enhancing science learning shows study gap either with the grade, study discipline or the method of study. Notably, Poudel et al. (2005) reported HoL in lesson boosts students' confidence, motivation and interest which resulted in better academic performance. However, their study focused on agriculture and environment programme with middle and higher-grade students.

Resmawati et al. (2018) remarked HoL enhances students' learning outcomes in all cognitive, affective, and psychomotor aspects. But their study focused on seventh grade with the science topic on temperature and heat matter. Similarly, Korn (2014) concluded that HoL provides an effective way to teach conceptual understanding of concepts, yet the study focussed on the learning of mathematics with HoL. Hence, it is apparent that there is a lack of research specifically focused on assessing the effectiveness of HoL in teaching sixth-grade science. Additionally, a few studies also concluded that HoL has influence on students' motivation and triggers their interest in science lessons (Tharchen et al. 2022; Rai, 2022). However, none of the studies mention the effectiveness of HoL in increasing the students' academic performance. Moreover, the studies were conducted in higher grades in learning of biology. Clearly, a noticeable gap exists in the study's methodology, context, focus group, and findings, which enhances the novelty of this research. Therefore, the key objective of this study is to bridge this gap by assessing the effectiveness of HoL in teaching science in grade six in Bhutanese classroom.

Methodology

The study employed an experimental design, which is a type of quantitative research. It aligned well with the nature of research. This approach involved quantifying qualities or variables within populations through numerical data collection and analysis. Kumari et al. (2023) pointed out that this design embedded statistical data gathering and inferential analysis. Given the study's objective to establish causal relationships among variables, the utilization of experimental design was reasonable.

Sampling

The study considered whole population as sample due to small population size (N=43). Crossman (2018) pointed out that such kind of sampling enables to make analytical generalization of finding, enables deeper insights for the study phenomena with reduced risk of missing potential insights from participants that are not included in the study. Thus, the study adopted the whole population method of sampling.

The study's participant was 43 students of two sections of grade six consisting of 26 females and 17 males. The participants were randomly assigned to either in control or experimental group consisting of 21 students. As per the rule of thumb, 15 is minimum numbers of sample required for an experimental study (Cohen et al., 2017).

Data Generation

The researcher assessed academic performance (dependent variable) while manipulating the extent of hands-on learning (independent variable) to determine its effectiveness in teaching science. Upon, random assignment of participants either in control or experimental group, the researcher administered the pre-test to gather the baseline data for both study groups. After the pre-test the control group was taught with traditional methods while experimental group was taught using HoL teaching strategies. Upon completion of teaching the targeted topics, a post-test was administered to both groups to evaluate the effectiveness of the HoL teaching strategies. The test tool for the data generation is using the paper pencil test paper and keeping research diary to record observations which may help during data analysis. The data source for the study was the 43 participants' (students), who were taught "chemical changes" and were assessed through pre-test and post-test. The pre-test ensured the comparability of the two variables before the treatment whereas post-test determined the immediate effects of treatment on the variables. These two tests showed and fast tracked the results (Rogers & Revesz, 2020) of the new teaching strategy.

Data Analysis

The researcher used the SPSS for analyzing the data. The descriptive statistics were calculated to understand the effectiveness of HoL while inferential analysis was used to make inferences of the findings of the study.

Reliability and Validity

The study's design (true experiment) exhibits higher reliability and validity. It is argued that random assignment enhances the internal validity of the study, because it ensures that there are no systematic differences between the participants in each group. Creswell (2012) explains that randomization of groups minimizes the potential impact of threats such as history, maturation, selection, and the interaction between selection and other factors. By reducing these threats, the validity of the research design is enhanced. In line with this, the study also exhibits external validity or generalizability firstly due to randomization of samples and secondly due to inclusion entire population in the experiment as highlighted by Street (1995).

The study's tool for data generation exhibits range of validity and reliability. The study used same instrument for the pre-test and post-test for data generation. Creswell (2012) described such enact standard procedures during the study minimizes the instrumentation threats which affect the validity of the tool. The test tool was also reliable as the researcher adopted themes for test development. Cronbach alpha reliability coefficient was found to be 0.82 which is higher than the acceptable value (0.70) suggested by Cohen et al, (2017).

Ethical Consideration

The researcher took care of all the ethical consideration and procedure including seeking approval from ethical review board, informed consent and protection of participant's right.

Findings and Discussion

Age and gender distribution of participants

The study adopted the census population sampling where forty-three grade six students (n=43) participated in this study among which 60.5% (n=26) were males and 39.5% (n=17) were females. Using randomization, these participants were further divided into experimental group (EG) and control group (CG) ensuring each participant had a fair chance to be in either group. There were 22 (51.16%) participants (M12, F10) in EG and 21 (48.87%) participants (M14, F7) in CG. Similarly, Ateş and Eryilmaz (2011) also deployed census population sampling (170 grade ninth students) and had similar number of participants in EG (53.84%) and CG (46.15%) in their study on effectiveness of hands-on and minds-on activities on students' achievement. Sadi and Çakıroglu's, (2011) study groups also had similar number of participants (EG= 51.42 %, CG=48.57%) out of 130 sixth grade students. Therefore, the study participants are equally distributed in order to avoid the bias related selection and distribution of participants.

The age of the participants ranged from tween (10-12 years old) to early teens. The majority of participants (72.09%) were tween aged. Sadi and Çakıroglu (2011) study participants' age was targeted to all 12 years old of sixth grade while Fakaruddin et al. (2023) participants were students aged 11 years. Similarly, this study's maximum numbers of participants are aged from 10 to 12. Thus, this study included more of the tween aged participants.

Participants' preference subjects

Table 4. 1

Participant's age with their favorite subject.

The study founded a clear preference for Science, Technology, Engineering, and Mathematics (STEM) subjects among participants. In the survey, 62.8% (n=27) of the participants indicated a preference for STEM subjects, while only 37.2% (n=16) preferred arts and language (English, Dzongkha, and social studies). This suggests that a significant majority of the participants in this study preferred STEM subjects compared to arts and language subjects.

		Favorite subject		
		STEM	Art & language	Total
Age	Tween (9-12 yrs.)	19	12	31
	Early Teens	8	4	12
Total		27	16	43

Both tween and early teen participants showed a preference for STEM subjects over arts and language. This trend was stronger in the early teens, where 66.7% favored STEM compared to 61.2% of tweens. Interestingly, despite the overall preference for STEM, a higher percentage of tweens (38.7%) still enjoyed arts and language compared to early teens (33.7%).

	Control group		Experiential group	
Pre-test	M= 35.83	SD=1.56	M=24.88	SD = 0.89
Post-test	M= 45.59	SD=1.56	M=62.15	SD =1.14

		Favorite subject		
		STEM	Art & language	Total
Age	Tween (9-12 yrs.)	19	12	31
	Early Teens	8	4	12
Total		27	16	43

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		STEM	Art & language	Total
Age	Tween (9-12 yrs.)	19	12	31
	Early Teens	8	4	12
Total		27	16	43

Academic Test Score for Study Groups (CG & EG)

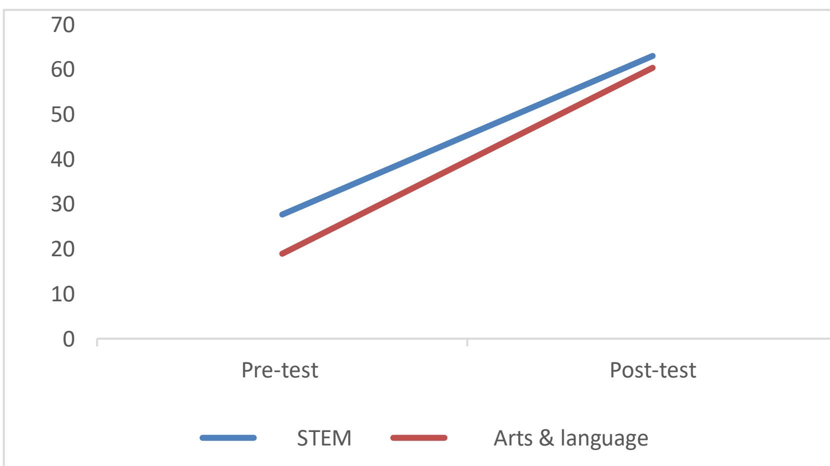
Table 4. 2

Descriptive statistics for control and experimental group's scores.

As presented in the Table 4.3, experimental group showed mean increase ranging from 24.88 to 62.15 in their level of science achievement from the pretest to post-test. However, the control group showed a mean increase ranging from 35.83 to 45.59 in their level of science achievement from the pretest to post-test. Therefore, experimental group shows a mean increase of 37.27 whereas the change of control group is 9.79 points on the learning scores which indicates that the students taught with HoL performed better score than the control group students. Numerous studies reported similar trends of increment in posttest over the pretest upon the implementation of HoL in their teaching (Ateş & Eryilmaz, 2011; Sadi & Çakıroglu, 2011; Su & Chen 2023). It is evident that HoL is effective in bringing positive academic achievement for the students.

Figure 4. 1

Experimental group's scores relation to participants' preferred subject.



The pre-test is slightly higher for participants who preferred STEM subjects (*M*=27.66, *SD* =1.14) compared to arts and language (*M*=18.93, *SD* = 1.85). The post-test results for STEM preferred participants (M=63.00, SD= 1.41) is also higher than the results of art and language (M=60.36, SD= 1.78) students. This illustrates that participants who preferred STEM performed better. Leibham et al. (2013) reported that early science interests for children are a critical supporting factor which fosters higher science achievement scores. Numerous studies mentioned that students' preference over a subject can impact their performance because when students enjoy a subject, they are more likely to be interested and actively participate in class. This can lead to better focus, deeper understanding, and a willingness to take on challenges which results in a positive relation between their interest in subject and achievement (Chang & Cheng, 2008; Jansen et. al., 2016; Kpolovie et al. 2014). Thus, it is evident that a participant's preference over the subject can affect the test scores in this study.

Table 4. 4

Experimental test's scores by the male and female participants.

	Male		Female	
Pre-test	M= 23.96	SD =0.81	M=26.00	SD =0.99
Post-test	M= 59.38	SD= 0.95	M= 65.5	SD =1.31

The pre-test mean score of male participants is (M= 23.96, SD= 0.81) is more than female (M= 26.00, SD= 0.99). Despite having the similar range of standard deviation, the mean score showed the differences (6.07). However, post-test mean scores for male participants (M= 59.38, SD=0.95) is slightly less than that of female participants (M=65.50, SD=1.31). On average, the female participants scored better than the male.

This finding aligned with previous research by Leibham et al. (2013), highlighting that girls typically exhibit greater interest in science than boys, influencing their academic performance in the subject. This existing pattern of score gaps based on gender is also reported in various studies (Quinn & Cooc, 2015; Glory & Ihenko, 2017; Ma, 2022). As discussed above the distribution of gender in study impacts the effectiveness of the HoL as an instructional strategy.

Correlation of among participants' test scores.

Table 4.5 *Correlation between Control group's pre and post scores.*

Variables	M	SD	1	2
1. Pre-test	35.83	1.69		
2. Post Test	45.59	1.52	474**	

**p<.05(two tailed)N=21

The mean scores of post-tests (M=45.59, SD= 1.52) more than the pre-test (M=35.83, SD=1.69) for the control group. A Pearson's correlation existed in a moderately positive relationship with statistically significant (*r* (19) =0.47, *P*<0.05) (Cohen et al., 2017). In other words, individuals who scored higher on the pre-test tended to also score higher on the post-test. The effect size, measured by Cohen's d, was d = 0.61, indicating a medium effect. The positive value of Cohen's d only indicates that one group scored higher than the other on average.

Table 4. 6

Correlation Between experimental group's pre and post scores.

Variables	M	SD	1	2
1. Pre-test	24.88	0.87		
2. Post-test	62.16	1.14	0.02**	

**p>.05(two tailed), N=21

The mean scores of post-tests (*M*=62.16, *SD*= 1.14) which is more than the pre-test (M=24.88, SD= 0.88) for the experiment group showed marginal difference. However, Pearson's correlation had a positive, weaker relationship with statistically significant *(r (19) =0.02, P < 0.05)* which indicates strength of the relationship is minimal where the improvement in scores wasn't strongly related to the initial (pre-test) performance of individual students. But the effect size, as measured by Cohen's *d*, was *d* = 3.86, indicating a v**ery strong impact** of the intervention.

Effectiveness of HoL

Table 4. 7

Groups		Paired Differences M	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
CG	Post-test –	9.76	1.65	3.61	17.29	2.23	2.70	20	.014
EG	Post-test –	37.27	1.42	3.01	43.53	31.01	12.38	21	.000

Paired Sample t- test within Group's (CG & EG) pre-test and post-test scores.

Both CG and EG exhibited statistically significant differences between their pre-test and post-test scores. The CG group showed a mean difference of 9.76 points (M_diff = 9.76), t (20) = 2.70, p = .014, while EG group displayed a larger mean difference of -37.27 points (M_diff = 37.27), t (21) = 12.38, p < .05. This suggests that both groups showed average increment in scores indicating statistical significance. However, EG showed larger size effect (Cohen's d=3.66) than CG (Cohen's d= 0.61) illustrating the greater average improvement.

Table 4. 8

Independent sample t-test across the groups (CG & EG) pre-test and post-test scores.

	Levene's Test for Equality of Variances		t-test for Equality of Means					
							95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Post-test	1.238	.272	4.05	41	.000	16.56385	24.81457	8.31314

Independent-samples t-tests revealed significant mean differences post-test scores between the CG and EG groups. The post-test scores displayed an effect size (Cohen's d = 1.23) with the CG group again having a significantly lower mean (M = 45.59, SD = 1.52) compared to EG (*M* = 62.16, SD = 1.13), (t (41) = -4.054, p < .05). The post-test scores showed the statistical significance (p<0.05, with larger magnitude of the difference between groups (substantive significance) (Cohen et al., 2017). The confidence intervals for the mean differences did not include zero, further confirming the statistical significance. These results suggested a substantial impact on learning score of experimental group brought about by the treatment.

The Independent-sample t-test revealed significant mean differences CG (M = 45.59, SD = 1.52) and EG (M = 62.16, SD = 1.13), (*t* (41) = 4.05, p = .000), where *P* value is lesser than significance value *p*=0.05. The significance was further determined by effect size Cohen's d= 1.23 depicting larger magnitude of the difference between groups signifying a substantial impact of HoL on student academic achievement. In line with it, sample's t value (4.05) falls in the zone of rejection below the calculated critical t value (2.02).

Therefore, the study found that HoL increases students' academic learning scores.

These findings aligned with previous research by Ateş and Eryilmaz (2011), Sadi and Çakıroğlu (2011), Su and Chen (2023), Fakaruddin et al. (2023), and Resmawati et al. (2018). These studies highlight the benefits of HoL in promoting a deeper understanding of scientific concepts, fostering critical thinking skills, and enhancing creative thinking in students boosting academic scores. This active learning approach allows students to learn "by doing" (Stull & Mayer, 2007; Triona & Klahr, 2007), leading to improved learning outcomes across cognitive, affective, and psychomotor domains.

The study indicates strong evidence that HoL is an effective strategy for teaching science to grade six students. By engaging students in manipulating objects and actively participating in the learning process, HoL fosters a deeper understanding of abstract scientific concepts and demonstrably improves student performance compared to traditional teaching methods.

Conclusion

The study underscores the transformative potential of Hands-on Learning in enhancing the academic achievement of primary school students in science. By actively engaging students in the learning process, HoL fosters a deeper understanding of complex scientific concepts, promotes critical thinking, and cultivates a lasting interest in STEM subjects. The findings advocate for the broader implementation of HoL in educational curricula, providing a pathway to more effective and inclusive science education. Future research should continue to explore and refine these approaches, ensuring that all students have the opportunity to benefit from active, hands-on learning experiences.

Implications of Findings

The results carry various implications for educational practice, curriculum planning, and development, as well as gender inclusivity and the promotion of STEM education. This study offers robust evidence supporting the implementation of hands-on learning (HoL) in primary science education. Implementing this approach can greatly enhance students' understanding of and engagement with scientific concepts. It's advisable for educators and curriculum developers to incorporate more interactive activities into science curricula to facilitate deeper learning and the cultivation of critical thinking skills.

Furthermore, the findings highlight the necessity for teaching strategies sensitive to gender differences, aiming to bridge performance gaps and encourage excellence in science among both boys and girls. The evident enthusiasm for STEM subjects among participants underscores the significance of fostering STEM education from an early age to nurture interest and proficiency in these fields.

Limitations

Despite its contributions, this study has limitations. The limitation includes the use of a single study tool and a narrow scope, along with brief study duration and constraints on resources. Specifically, the study's scope was confined to one primary school and a single grade, potentially limiting its representativeness across broader student populations and lacking data triangulation. Additionally, the research concentrated solely on short-term academic performance, neglecting the evaluation of long-term retention and practical application of acquired knowledge. Furthermore, the implementation of hands-on learning necessitates resources and training that may not be universally accessible in all educational environments, which could restrict the applicability of the study's findings.

Future Research Directions

Future investigations should focus on overcoming limitations and delving into several key areas, including conducting longitudinal studies, the diverse participant demographics and comparative analyses. It will be beneficial to undertake longitudinal inquiries to gauge the enduring effects of HoL on student academic achievements. Expanding the research to include diverse educational settings and larger sample sizes to enhance generalizability. Additionally, comparative studies of HoL against alternative pedagogical methods, such as digital or blended learning, is imperative for discerning the most efficient strategies across different educational contexts.

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