© IJARW | ISSN (O) - 2582-1008
December 2024 | Vol. 6 Issue. 6
www.ijarw.com

STUDENT'S HANDS-ON LEARNING OPPORTUNITIES AND LONG-TERM RETENTION OF KNOWLEDGE IN SCIENCE

Mar Jun M. Golosino [1], Dr. James L. Paglinawan [2]

[1]*Graduate Student, Central Mindanao University*
[2]*Associate Professor IV, Central Mindanao University*

ABSTRACT

This study investigates the relationship between students' hands-on learning opportunities and their long-term retention of knowledge in science among Grade 10 students at Bangcud National High School. Utilizing a descriptive-correlational research design, the study involved 85 participants selected through random sampling. Data were collected through validated questionnaires and analyzed using the Statistical Package for the Social Sciences (SPSS). The findings reveal that students rated the frequency of hands-on activities with a mean score of 3.59, indicating moderate engagement, while skill development through these activities received the highest score of 3.74. Additionally, students expressed positive attitudes toward science, with a mean score of 3.67. In terms of long-term knowledge retention, the overall mean score was 3.64, suggesting high retention capabilities linked to hands-on experiences. Significant positive correlations were identified: frequency of hands-on activities correlated with retention of knowledge (r = 0.541), skill development with application of knowledge (r = 0.592), and attitudes towards science with perceived effectiveness of hands-on learning (r = 0.694). These results underscore the importance of hands-on learning experiences in enhancing knowledge retention and fostering positive attitudes towards science education. The study recommends increasing the frequency of hands-on activities in the curriculum and providing professional development for educators to enhance teaching strategies. Ultimately, these findings highlight the necessity of integrating hands-on learning opportunities to improve student engagement and success in science education.

Keyword: Hands-on Learning, Knowledge Retention, Long-term Retention, Science

1. INTRODUCTION

In the evolving landscape of education, hands-on learning emerged as a pivotal pedagogical approach, particularly in the field of science. This research aimed to explore the relationship between students' hands-on learning opportunities and their long-term retention of knowledge in science, focusing specifically on Grade 10 students at Bangcud National High School in an urban setting during the 2024 school year.

Hands-on learning, characterized by active participation and experiential engagement, had been shown to enhance students' understanding and retention of scientific concepts which was supported by the study of Haury and Rillero (2015) that hands-on learning approach involves the child in a total learning experience which enhances the child's ability to think critically. Yet it is obvious therefore, that any teaching strategy that is skilled towards this direction can be seen as an activity-oriented teaching method (Hands-on-approach).

Hands-on-approach has been proposed as a means to increase students' academic achievement and understanding of scientific concepts by manipulating objects which may make abstract knowledge more concrete and clearer. In fact, the study of Obanya (2012) in his convocation lecture confirmed the above statement by adding that the average retention rate of learning by lecture is 5% while that of practice by doing (Activity-oriented) is about 75%. Hence, it can be seen that retention rate increases progressively with the use of more interactive and activity-oriented teaching methods.

However, despite its recognized benefits, there remained a significant gap in understanding how these opportunities directly influenced long-term knowledge retention among students. For example, Holstermann et al. (2010) noted that

hands-on learning fosters greater interest and engagement among students compared to traditional instructional methods, yet the long-term effects on retention require further investigation. This research sought to address this gap by examining the specific dimensions of hands-on learning frequency of activities, skill development, and attitudes towards science and their correlation with long-term knowledge retention.

This study examined three primary variables related to hands-on learning. The first variable was Frequency of Hands-On Activities, which assessed how often students engaged in practical experiments and projects; a higher frequency was expected to correlate positively with knowledge retention in science concepts. The second variable was Skill Development through Hands-On Learning, evaluating the extent to which hands-on activities fostered essential scientific skills such as critical thinking, problem-solving, and technical abilities; enhanced skill development was anticipated to improve knowledge application. The third variable was Attitudes towards Science and Technical Education, capturing students' perceptions and feelings about science as a discipline; positive attitudes were hypothesized to enhance engagement and motivation, further supporting retention. These variables were correlated with two key aspects of long-term retention: Retention of Knowledge over Time, which referred to the ability to recall and use scientific information after a significant period, and Application of Knowledge, which assessed how well students could apply learned concepts in practical scenarios.

Several studies provided insight into the relationship between hands-on learning and knowledge retention. For instance, a study by Hattie and Donoghue (2016) found that experiential learning significantly enhanced student engagement and understanding, which are critical for long-term retention. Additionally, Prince and Felder (2006) highlighted that active learning strategies led to improved conceptual understanding and retention rates compared to traditional lecture-based approaches. Another study conducted by Fariborz et al. 2023) there finding highlights that hands-on experience significantly improves both technical and soft skills, including problem-solving, teamwork, and critical thinking, which are essential for professional success.

Locally, a study conducted by Nadia et al. (2024) they found that Project-Based Learning (PBL) significantly enhances academic achievement, particularly in science subjects, with a mean weighted effect size of 0.652, indicating a positive influence on student performance and retention of scientific concepts over time. Another study conducted by Ryland et al. (2024) which explores the relationship between scientific attitude and academic achievement, highlighting that fostering a positive scientific attitude can enhance students' engagement and performance in science, thereby supporting the notion that such attitudes amplify the benefits of hands-on learning.

The primary objective of this research was to investigate the relationship between students' hands-on learning opportunities and their long-term retention of knowledge in science, focusing on various dimensions of hands-on learning and their impact on students' ability to retain and apply scientific concepts effectively. Specifically;

1. To assess the level of students' hands-on learning opportunities in terms of:

- Frequency in Hands-On Activities
- Skill Development through Hands-On Learning
- Attitudes towards Science and Technical Education

2. To evaluate the level of Long-Term Retention of Knowledge in Science among Grade 10 students concerning:

- Retention of Knowledge over Time
- Application of Knowledge
- Perceived Effectiveness of Hands-On Learning

3. To determine the correlation between:

- Frequency in Hands-On Activities and Retention of Knowledge Over Time
- Skill Development through Hands-On Learning and Application of Knowledge
- Attitudes towards Science and Technical Education and Perceived Effectiveness of Hands-On Learning

2. METHODOLOGY

This section outlined the methodology utilized in the study titled "Students' Hands-on Learning Opportunities and Long-term Retention of

Knowledge in Science." The methodology was structured into four key components: research design, sampling method, data analysis, and data collection.

2.1 Research Design

The study employed a descriptive-correlational research design, which was particularly suitable for examining the relationship between students' hands-on learning opportunities and their long-term retention of knowledge in science. With a robust sample of 85 respondents, this design allowed the researcher to systematically gather data that described the current state of these variables and to explore potential correlations between them.

By utilizing this approach, the researcher identified patterns and relationships without manipulating the independent variable. This methodology provided a clear understanding of how hands-on learning experiences may have influenced knowledge retention among the participants, thereby enriching the overall findings of the study

2.2 Sampling Method

For this study, the researcher utilized a random sampling method to select respondents from Grade 10 students at Bangcud National High School. This approach ensured that every student had an equal chance of being chosen, which enhanced the representativeness of the sample and minimized selection bias. The random selection of participants helped to ensure that the findings could be generalized to the broader population of Grade 10 students within the school, thereby increasing the validity of the study's conclusions.

2.3 Data Analysis

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS). This statistical tool was well-suited for handling various types of data analyses, including descriptive statistics and correlation coefficients. By employing SPSS, the researcher accurately ran analyses to determine the strength and direction of relationships between hands-on learning opportunities and long-term retention of knowledge. The use of SPSS facilitated a comprehensive understanding of the data, allowing for informed interpretations and conclusions based on statistical evidence.

2.4 Data Collection

Before conducting the actual survey to gather the data from the respondents, the researcher first sought approval from the school principal through a formal letter. This step was crucial to ensure ethical compliance and institutional support for the study.

Given that the target respondents were under 18 years old, it was essential to secure both an assent form from each student and a consent form from their parents or guardians prior to conducting the study. This process respected ethical standards in research involving minors and ensured informed participation.

To develop the survey instruments, the researcher requested permission from two previous researchers to adapt their questionnaires. Prior to actual data collection, these patterned questionnaires underwent a content validation process involving three distinguished personnel in the field of education. Following validation, a pilot test was conducted to determine reliability using Cronbach's alpha, ensuring that the questions were consistent and reliable for measuring the intended constructs.

This methodology provided a clear framework for conducting research on how hands-on learning opportunities impacted long-term retention of knowledge in science among Grade 10 students at Bangcud National High School.

3. RESULTS AND DISCUSSIONS

This section includes the presentation of data gathered and the comprehensive discussion, interpretation, and implication of the findings of the study. Results were presented in tables, which were then analyzed and interpreted. The order of the presentation follows the sequence of the problems identified in the study.

Table 1. Summary mean of the three independent sub variables

Sub-variable	Mean	Descriptive Rating	Qualitative Interpretation
Frequency of Hands-on Activities	3.59	Agree	High Hands-On Engagement
Skill Development through Hands-On Learning	3.74	Agree	High Hands-On Engagement
Attitudes towards Science and Technical Education	3.67	Agree	High Hands-On Engagement
Overall Mean	**3.67**	**Agree**	**High Hands-On Engagement**

Range	Descriptive Meaning	Qualitative Interpretation
4.51-5.00	Strongly Agree	Very High Hands-On Engagement
3.51-4.50	Agree	High Hands-On Engagement
2.51-3.50	Neutral	Moderately High Hands-On Engagement
1.51-2.50	Disagree	Low Hands-On Engagement
1.00-1.50	Strongly Disagree	Very Low Hands-On Engagement

The summary of the mean scores for the three independent sub-variables related to students' hands-on learning opportunities, as presented in Table 1, provides a comprehensive overview of their engagement levels across different dimensions.

The sub-variable "Skill Development through Hands-On Learning" received the highest mean score of 3.74, reflecting a strong consensus among students that those hands-on activities significantly enhance their skills. This suggests that students recognize the value of practical experiences in developing essential competencies such as problem-solving, teamwork, and critical thinking. In conformity this finding, Idowu et al. (2020) asserted that hands-on and minds-on activities are beneficial for improving academic performance, retention of knowledge, and fostering positive attitudes towards Basic Science among junior secondary school students.

Following is the sub-variable "Attitudes towards Science and Technical Education," which scored 3.67, indicating that hands-on learning positively influences students' interest and motivation in these subjects. This aligns with previous findings that highlight the role of experiential learning in making science more engaging and relevant. The research conducted by Holstermann et al. (2009) concluded that students with experience in specific hands-on activities generally showed higher interest in those activities compared to students without such experience, indicating a positive influence of hands-on activities on interest. Additionally, the study made by Güner, Tural (2021) concluded that hands-on instructions significantly enhance students' cognitive achievement in the topic 'Gas Pressure' which is topic in science, showing greater improvement in correct responses and a decrease in wrong responses compared to traditional instructions, emphasizing the effectiveness of this teaching strategy.

The sub-variable "Frequency of Hands-on Activities" scored slightly lower at 3.59, still within the "Agree" range but indicating that students feel there is room for improvement in the frequency of these activities. This suggests a need for educators to increase the integration of hands-on experiences into the curriculum to further enhance student engagement. Thus, the study conducted by Munir et al. (2013) strongly advocates for the inclusion of hands-on activities in science education, highlighting their positive impact on student achievement while also recognizing the need for further investigation into

their long-term effects and varying outcomes across different contexts.

In addition, the study conducted by Cecilia O. in 2015 highlights the positive impact of the Hands-on-approach on student academic performance in mathematics and science. She found that students who engaged in hands-on activities showed significant improvement in their test scores and overall understanding of the subjects. Additionally, the research indicated that both students and teachers were receptive to this activity-oriented teaching method, recognizing its benefits for learning.

Table 2. Summary of all the dependent sub variables

Sub-variable	Mean	Descriptive Rating	Qualitative Interpretation
Retention of Knowledge Over Time	3.57	Agree	High knowledge retention
Application of Knowledge	3.62	Agree	High knowledge retention
Perceived Effectiveness of Hands-On Learning	3.72	Agree	High knowledge retention
Overall Mean	**3.64**	**Agree**	**High knowledge retention**

Legend

Range	Descriptive Meaning	Qualitative Interpretation
4.51-5.00	Strongly Agree	Very High Knowledge Retention
3.51-4.50	Agree	High Knowledge Retention
2.51-3.50	Neutral	Moderately High Knowledge Retention
1.51-2.50	Disagree	Low Knowledge Retention
1.00-1.50	Strongly Disagree	Very Low Knowledge Retention

The summary of the dependent sub-variables related to students' knowledge retention in science, as presented in Table 2, provides a comprehensive overview of their perceptions regarding the impact of hands-on learning. The overall mean score of 3.64 categorizes students' engagement as "Agree," indicating a generally positive view of their knowledge retention capabilities as influenced by hands-on experiences. This result aligned with the work conducted by Aric, et al. (2009) that both simulation and hands-on labs are more effective than traditional demonstrations for memory retention. Another study conducted by Oludare et al. (2024) highlights that the use of hands-on learning pedagogy as a means to enhance the educational experience of engineering students, leading to improved understanding, engagement, and success in their studies.

Each sub-variable reflects a strong consensus among students regarding the effectiveness of hands-on learning in enhancing their retention of knowledge. The sub-variable "Perceived Effectiveness of Hands-On Learning" received the highest mean score of 3.72, suggesting that students strongly believe in the benefits of practical experiences for improving their understanding and recall of scientific concepts. This is further supported by the sub-variable "Application of Knowledge," which scored 3.62, indicating that students feel confident in applying what they have learned from hands-on activities to real-life situations and future academic tasks. The aforementioned statements were in congruence to the work conducted by Louise et al.

(2020) where they found out that students attending voluntary hands-on microbiology lab sessions scored higher on related exam questions, indicating that active learning enhances knowledge retention and application, supporting the correlation between hands-on learning and long-term retention in science education. Similarly, Prince (2014) highlights that active learning technique, including hands-on activities, foster deeper understanding and retention of complex concepts among students

The sub-variable "Retention of Knowledge over Time" scored slightly lower at 3.57 but still falls within the "Agree" range, reflecting a positive perception that hands-on activities contribute to their long-term retention of knowledge. This suggests that while students recognize the benefits of these experiences, there may be some variability in their ability to consistently recall information over extended periods. This is further affirmed by Awodun, A. O., & Osuntuyi, E. O. (2021) where they stated that hands-on activities significantly enhance classroom concentration, knowledge retention, creativity, and problem-solving skills among students. Thus, their research underscores the importance of practical engagement in improving educational outcomes in technical fields. In addition, Lazonder and Ehrenhard (2014), noted that the tactile engagement provided by hands-on activities enhances cognitive processing through multiple modalities, leading to better retention and retrieval of information. Alkan (2016) also emphasizes that hands-on learning not only improves retention but also boosts confidence in applying scientific concepts.

Table 3. Correlation among Independent sub-variables and dependent sub-variables

Sub variables		**Retention of knowledge Over Time**	**Application of Knowledge**	**Perceived Effectiveness of Hands-On Learning**	**Decision**	**Remarks**
Frequency of Hands-on Activities	Pearson Correlation Sig. (2-tailed)	**.** 541(**) .000			Reject0	Significant
Skill Development through Hands-on Learning	Pearson Correlation Sig. (2-tailed)		.592(**) .000		Reject0	Significant
Attitudes Towards Science and Technical Education	Pearson Correlation Sig. (2-tailed)			.694(**) .000	Reject0	Significant

** Correlation is significant at the 0.01 level (2-tailed).

a Listwise N=85

The analysis of the correlation among various sub-variables related to students' knowledge retention in science, as presented in Table 3, reveals significant insights into the relationships between hands-on learning activities and their impact on retention, application of knowledge, and

perceived effectiveness. The results indicate strong positive correlations among all sub-variables, suggesting that increased engagement in hands-on activities is associated with improved retention of knowledge, enhanced ability to apply what has been learned, and a greater perception of the effectiveness of these experiences. In conformity to the result, Louise et al. (2020) found out that students attending voluntary hands-on microbiology lab sessions scored higher on related exam questions, indicating that active learning enhances knowledge retention and application, supporting the correlation between hands-on learning and long-term retention in science education. On a similar note, the study conducted by David, S, Byrne. (2022) highlighted that hands-on learning through simulations significantly enhances long-term knowledge retention in forensic science, as participants demonstrated stable comprehension of major theories, despite some decline in specific terminology, illustrating the effectiveness of experiential learning methods. In contrast, the study of Ollero, J. C. (2023) found a correlation of 0.151 between retention levels and learning styles, suggesting a very weak relationship between these variables

Specifically, the frequency of hands-on activities shows a Pearson correlation coefficient of 0.541 ($p < 0.01$) with retention of knowledge over time, indicating a significant positive relationship. This suggests that students who participated more frequently in hands-on activities tend to retain scientific concepts better over the long term. This finding is supported by the work of Carisa et al. (2014) where they explore how hands-on experiments in discussion labs enhance students' understanding and retention of Statics concepts, suggesting that experiential learning can significantly improve long-term retention of knowledge in engineering courses, as evidenced by improved test scores and reduced course retakes.

Similarly, skill development through hands-on learning correlates positively with the application of knowledge, with a coefficient of 0.592 ($p < 0.01$). This finding implies that as students develop practical skills through these activities, they are more likely to effectively apply their knowledge in real-world situations. This finding is supported by the study of Mutlaq, F. et al. (2018) where they concluded that knowledge retention is influenced by hands-on experience, as practical application enhances the retention of knowledge. Thus, this relationship is significant, reflecting the importance of experiential learning in developing both human and intellectual capital within organizations.

Furthermore, the strongest correlation is observed between attitudes towards science and technical education and perceived effectiveness of hands-on learning, with a Pearson coefficient of 0.694 ($p < 0.01$). This robust relationship indicates that positive attitudes significantly enhance students' perceptions of how effective hands-on activities are in their learning processes. In consonance with this, the study of Ibwari et al. (2024) found a significant effect of hands-on instruction on pupils' retention in cultural and creative arts, indicating that increased frequency of hands-on learning activities enhances knowledge retention over time, promoting better understanding and long-term memory of the subject matter. Another study made by Aaron et al. (2001) indicated that hands-on occupations significantly enhance memory recall compared to passive learning, suggesting a positive correlation between hands-on learning frequency and knowledge retention, particularly in individuals with cognitive deficits, as evidenced by improved recall performance in the hands-on group. Likewise, the study of Christos et al. found that hands-on learning significantly enhances knowledge acquisition, inquiry skills, and measurement skills in electronic circuits. Students engaged in hands-on activities outperformed those in virtual environments, indicating a strong correlation between skill development and practical application of knowledge

Given these findings, the decision to reject the null hypothesis is warranted across all correlations, confirming that there are significant relationships between the variables studied. The remarks associated with these results emphasize the critical role that hands-on experiences play in shaping effective learning environments.

Furthermore, these significant correlations highlight the importance of integrating hands-on learning experiences into science education. Such activities not only enhance knowledge retention and application but also positively influence students' attitudes towards science, leading to increased engagement and interest in the subject. Therefore, educators should prioritize incorporating more hands-on learning

opportunities into their curricula to maximize student engagement and success in science education.

The overall mean score of 3.67 categorizes students' engagement as "Agree," indicating a generally positive perception of hands-on learning experiences. Thus, the consistent ratings across all three sub-variables suggest that students value hands-on learning as an effective approach to education. However, the differences in mean scores indicate specific areas for potential enhancement. Hence, by focusing on increasing the frequency of hands-on activities and ensuring that these experiences are effectively integrated into skill development and attitudes towards science, educators can create a more engaging and impactful learning environment. This approach not only fosters greater interest in science and technology but also equips students with the practical skills necessary for future academic and career success. In consonance with the findings, a meta-analysis by Freeman et al. (2014) found that active learning approaches lead to higher examination scores compared to traditional lectures, reinforcing the value of hands-on learning experiences in enhancing educational outcomes. These studies collectively underscore the necessity of incorporating hands-on learning strategies into educational curricula to cultivate an engaging and effective learning environment for students in science and technical education. Similarly, a study by Hattie (2019) emphasizes that experiential learning strategies significantly improve student engagement and achievement levels.

4. CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, the following conclusions were made:

4.1 Students' Hands-on Learning Opportunities

Frequency of Activities: Students rated the frequency of hands-on activities at 3.59, indicating a moderate level of engagement but highlighting the need for improvement.

Skill Development: This aspect received the highest score of 3.74, showing that students believe hands-on activities significantly enhance their skills.

Attitudes towards Science and Technical Education: With a mean score of 3.67, students generally maintain positive attitudes influenced by hands-on learning.

4.2 Long-Term Retention of Knowledge in Science

Retention Over Time: Students reported a mean score of 3.57, reflecting a positive view of their ability to retain knowledge.

Application of Knowledge: Scoring 3.62, students feel confident in applying what they learned through hands-on experiences.

Effectiveness of Hands-On Learning: A score of 3.72 indicates strong belief in the effectiveness of hands-on learning for improving understanding and recall.

4.3 Correlation Between Variables

Frequency and Retention: A significant positive correlation ($r = 0.541$) suggests that more frequent hands-on activities lead to better knowledge retention.

Skill Development and Application: A positive correlation ($r = 0.592$) indicates that skill development enhances the ability to apply knowledge effectively.

Attitudes and Effectiveness: The strongest correlation ($r = 0.694$) suggests that positive attitudes significantly enhance perceptions of hands-on learning effectiveness.

4.4 Recommendations

Increase Hands-on Activities: Integrate more lab sessions, field trips, and practical projects into the curriculum to enhance engagement.

Educator Training: Provide professional development for teachers on effective hands-on teaching strategies to improve learning experiences.

Further Research: Conduct longitudinal studies to investigate the long-term effects of hands-on learning on knowledge retention across different educational contexts, validating current findings and enhancing understanding of effective teaching strategies

5. ACKNOWLEDGEMENT

I would like to extend my heartfelt gratitude to several individuals and groups who contributed to the success of this study. First and foremost, I

thank our instructor, Dr. James L. Paglinawan, for his guidance and support throughout the research process

I also wish to express my appreciation to my Sir Salley Moreno and the Grade 10 respondents from Bangcud National High School, whose participation was invaluable to this study. Your insights and feedback made this research possible.

Additionally, I am grateful to my content validators for their careful review and validation of the survey questionnaire, ensuring the study's reliability and relevance.

Lastly, I give thanks to the Almighty God for providing the strength, wisdom, and perseverance needed to complete this work. Your guidance has been a constant source of inspiration. Thank you all.

6. REFERENCES

[1] Aaron, M., Eakman., David, L., Nelson. (2001). The Effect of Hands-on Occupation on Recall Memory in Men with Traumatic Brain Injuries. Occupational Therapy Journal of Research, 21(2):109-114. doi: 10.1177/153944920102100205

[2] Alkan, A. (2016). Hands-on learning: Improving retention and confidence in applying scientific concepts.

[3] Aric, Bryant., Koenraad, Alexander, Gieskes., R.T.R., McGrann. (2009). The role of active learning through laboratory experimentation pertaining to memory retention in first-year engineering programs. 1295-1300. doi: 10.1109/FIE.2009.5350597

[4] Awodun, A. O., & Osuntuyi, E. O. (2021). Impact of hands-on activities on students' academic achievement in Science and Technical Education in College of Education, Ikere-Ekiti, Ekiti State, Nigeria. International Journal of Social Science and Humanities Research, 4(7), 131-137. Retrieved from http://ijojournals.com/index.php/ssh/index

[5] Carisa, H., Ramming., John, J., Phillips. (2014). Improving Retention by Use of Hands-on Experiments in Statics.

[6] Cecilia O. (2015). The Impact of Hands-On-Approach on Student Academic Performance in Basic Science and Mathematics. Higher Education Studies, 5(6), 47-50.

[7] Christos, Tokatlidis., Sokratis, Tselegkaridis., Sophia, Rapti., Theodosios, Sapounidis., Dimitrios, K., Papakostas. (2024). Hands-On and Virtual Laboratories in Electronic Circuits Learning—Knowledge and Skills Acquisition. Information, 15(11):672-672. doi: 10.3390/info15110672

[8] David, S, Byrne. (2022). Gauging Long-Term Knowledge Retention of Forensic Science: A Follow-Up Study of College Students Who Participated in a Crime Scene Simulation. Journal of social sciences research, 18:15-24. doi: 10.24297/jssr.v18i.9176

[9] Fariborz, Aqaie, Moqaddam. (2023). The Impact of Experiential Learning on the Development of Practical Skills in Internships. 3(2):31-40. doi: 10.61838/jsied.3.2.4

[10] Güner, Tural. (2021). Impact of Hands-on Instructions on Students' Cognitive Achievement. MIER Journal of Educational Studies, Trends and Practices, 8(2):164-170. doi: 10.52634/MIER/2018/V8/I2/1390

[11] Holstermann, N., Grube, D., & Bogeholz, S. (2009). Hands-on Activities and Their Influence on Students' Interest. Research in Science Education, 40(6), 743-757. https://doi.org/10.1007/s11165-009-9142-0

[12] Holstermann, N., Grube, D., & Bogeholz, S. (2010). Hands-on Activities and Their Influence. Res Sci Educ, 743-757. doi:10.1007/s11165-009-9142-0

[13] Hattie, J., & Anderman, E. M. (2019). Visible Learning Guide to Student Achievement. In Routledge eBooks. https://doi.org/10.4324/9781351257848

[14] Ibwari, Caroline, Dike., Mkpoikanke, Sunday, Out., Adannia, Amalachukwu, Dike. (2024). Effect of Hands-On Instructional Approach on Pupils' Achievement and Retention in Cultural and Creative Arts. International Journal of Professional Business Review, doi: 10.26668/businessreview/2023.v9i1.4207

[15] Idowu, Daniel, Oludipe., Ayodele, Isaac Ojediran., Oluwaseun Adeyinka Kareem.(2020). Effect of hands-on/minds-on activities on junior secondary school basic science students' learning outcomes in Ogun State Nigeria . 3(1):52-67.

[16] Louise B., Lawson C.M., Lind J.W., Gibson K.H., Höner zu Bentrup . (2020). Do Voluntary Lab-Based Active Learning Sessions Impact Medical Student Knowledge Retention?. Medical science educator , 30(2):823-831.doi: 10.1007/S40670-020-00956-7

[17] Mempin K.T.(2024). Science-related factors on learners' academic performance.

International Journal of Research Publication and Reviews ,5(4),1244-1254.

[18] Mutlaq F.A.-B.(2018). Retaining Knowledge, Human , and Intellectual Capital . Information and Knowledge Management ,8(2):36-40.

[19] Nadia Rehman ., Xiao Huang ., Samia Batool ., Irum Andleeb ., A ., Mahmood . (2024). Assessing the Effectiveness of Project-Based Learning: A Comprehensive Meta-Analysis of Student Achievement between 2010 and 2023 . doi: 10.12982/cmujasr .2024 .015

[20] Oludare Adegbola Owolabi ., Hannah Abedoh ., Pelumi Abiodun ., Sotonye Ikiriko ., Ayodeji Wemida ., Chukwuemeka Duru ., Nkiruka Jane Nwachukwu ., Mojeed Bello ., Olushola Emiola-Owolabi ., Steve Efe ., Celeste Chavis ., S Ahangari ., James Hunter ., Frank Efe ., Amrita Bhandari ., Gbeke Oguntimein ., Mehdi Shokouhian ., Petronella A ., James-Okeke N.B . Shourabi Mulugeta Dugda Maia Freeman K.Bista Uttam Gaulee J.Ladeji-Osias . (2024) . Hands-on Learning Pedagogy in Teaching Concepts Relevant in the Analysis , Design , and Maintenance of Transportation Infrastructure Systems . Transportation Research Record , doi : 10 .1177 /03611981241242067

[21] Prince N.(2023). Exploring the classroom tools used to develop students' higher order thinking skills in middle and high school STEM courses . https://doi.org/10 .17760/d20483505

[22] Ryland, Mr., Jyoti, Gangrade, -. (2024). The Influence of Scientific Attitude on Academic Achievement among Secondary School Students. International Journal For Multidisciplinary Research, 6(3) doi: 10.36948/ijfmr.2024.v06i03.20725