IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388, p- ISSN: 2320-737x Volume 14, Issue 6 Ser. 4 (Nov. – Dec. 2024), 39-47
www.iosrjournals.org

Scientific Hands-On Activities And Its Impact On Academic Success Of Students: A Systematic Literature Review

Thomas Nipielim Tindan,
Department Of Science And Education, C. K. TedamUniversity Of Technology And Applied Sciences, Ghana.

Clement Asakedola Anaba,
Department Of Science And Education, C. K.Tedam University Of Technology And Applied Sciences, Ghana.

Abstract
This systematic literature review (SLR) synthesizes empirical studies on hands-on science education and academic success. The review selects and evaluates studies on how hands-on activities improve students' academic performance transparently, reducing bias and ensuring consistency. The study examined experimental, quasi-experimental, and observational empirical articles from 2000 to 2024 from Google Scholar, PubMed, ERIC, Scopus, and Web of Science. Peer-reviewed, science education-focused, academic success studies were required. After rigorous relevance and quality screening and careful study design, sample size, and data collection method examination, we included 103 articles. The review found that hands-on science improves academic and cognitive performance. Science education becomes more engaging when students' conceptual understanding, critical thinking, problem-solving, and engagement improve. Integrating theory and practice in hands-on learning creates dynamic academic and professional development environments. Though promising, classroom hands-on activities are difficult to implement due to time, materials, and teacher training constraints. Teachers and policymakers who prefer traditional methods may also resist hands-on learning. Research suggests funding, teacher training, and aligning assessment systems with experiential learning outcomes to promote innovative teaching.

Keywords: *Scientific, Hands-on, Success, Academic, Learning*

Date of Submission: 24-11-2024 Date of Acceptance: 04-12-2024

I. Introduction

Engaging students with materials and phenomena promotes critical thinking and problem-solving (Bhaduri & Copeland, 2021). Many instructional methods affect senior high school student success. Hands-on science education has grown in popularity (Ekmekci & Gulacar, 2015). Science concepts are better retained through hands-on learning (Christensen et al., 2015). Years of lectures have stifled student engagement. Hands-on, interactive learning is getting better at improving students' scientific understanding and academic performance. This approach is crucial as senior high school students transition to more complex subjects and prepare for higher education or careers that require critical thinking and problem-solving (Huppert et al., 2002). As technology and information grow, science education helps students learn. Success in school and work requires critical thinking, problem-solving, and evidence-based reasoning (Taraban et al., 2007). Science class helps students understand natural phenomena and make health, environmental, and technological decisions. Interdisciplinary learning begins with science success affecting math, engineering, and technology. Areepattamannil (2012) states that science improves students' analytical, cognitive, and academic skills. Science education leads to STEM careers, the fastest-growing and most requested worldwide. Employers value scientifically trained workers because they are logical, adaptable, and innovative (McCarthy, 2005). Governments, schools, and policymakers are prioritizing science education at all levels to meet STEM jobs demand.

Along with academic and professional benefits, science education promotes scientific literacy, which solves global problems. Climate change, pandemics, and sustainable development are better addressed by scientifically literate people (Knox et al., 2003). Science education helps individuals, communities, and nations grow. Late-19th- and early-20th-century science education was rich in hands-on activities. Active participation was promoted to boost student engagement and scientific understanding as constructivist theories gained popularity (Markowitz, 2004). Practical lessons and early lab experiments helped students apply theory to real-world situations. Students interacted with scientific phenomena through dissections, chemistry experiments, and fieldwork (Pine et al., 2006). These methods connected abstract concepts to real-world applications to improve science comprehension. Experiential learning was John Dewey's focus. Dewey believed students should learn by doing; not just hearing (1938). His work inspired educators to prioritize active learning, laying the groundwork for inquiry-based science classes.

Through hands-on learning, the early 20th century Progressive Education Movement fostered creativity, critical thinking, and collaboration. It advocated a holistic science education that met students' developmental needs (Ekmekci & Gulacar, 2015). This improved experiential learning in schools. Technology and the Space Race made science education more important after the war. Govt. and school science curricula included lab work, project-based learning, and other experiential methods to meet national scientific and technological goals (Klahr et al., 2007). During the 1960s, inquiry-based learning encouraged students to ask questions, experiment, and draw conclusions. Science and active learning characterized this method (Holstermann et al., 2010). To improve student comprehension and retention, science education reforms focused on inquiry-based learning. Science education today emphasizes hands-on activities at all levels. Simulations, field trips, labs, and interactive digital tools are examples. Practical experiences help students apply theory to real-world situations (Christensen et al., 2015). Research shows that hands-on activities outperform lectures. Active learning improves science optimism, critical thinking, and retention (Yilmaz et al., 2010). These results show how experiential learning improves science.

Unfortunately, resource constraints, poor teacher training, and rigid curricula make hands-on activities difficult. These barriers can hinder experiential learning in resource-constrained settings (Yilmaz et al., 2010). Technological advances have transformed hands-on activities. Interactive simulations, augmented reality, and virtual labs are cheaper and more accessible than experiments (Brinson, 2015). Many schools teach 21st-century skills hands-on. Singapore and Finland excel at experiential learning (Corter et al., 2011). These methods prepare students for future challenges— as shown by their global adoption. Hands-on science education has shaped academic and professional development throughout history. Fundamental to science education, these methods foster critical thinking, creativity, and practicality. Resolving issues and using technology will boost adoption. Lecture-based science and rote memorization often fail modern educational standards. Student disengagement is serious. These methods make students passive, which can separate theory from practice. For understanding complex scientific concepts and lifelong learning, this disconnect hinders critical thinking and problem-solving (Hampden-Thompson & Bennett,2013). Another issue is student lack of practical application. Students without experience may struggle to apply abstract scientific principles. Weak understanding and retention result from this gap. Students may memorize formulas or theories for exams but not understand their principles or practical relevance, preventing them from applying this knowledge in new or real-world situations (Demirhan & Şahin, 2021; Walan, 2019).

Traditional methods ignore diverse student learning needs. Some learners prefer visual, auditory, or kinesthetic learning. Theory-based teaching ignores these differences, leading many students to disengage or not understand. This approach fails to develop soft skills like teamwork, creativity, and communication, which science and technology careers increasingly value (Hsiao et al., 2019). Finally, traditional science instruction often hinders technology and interdisciplinary thinking. As science and education evolve, students need digital simulations, virtual labs, and collaborative technologies to learn 21st-century skills. Traditional approaches struggle to incorporate these advances due to static curricula and outdated pedagogical models. This limitation makes educationunprepared for fast-changing scientific and professional demands (Erickson et al., 2020).

Objectives of the Review

- To evaluate the impact of scientific hands-on activities on students' academic success.
- To identify gaps in existing literature.

II. Methodology

This systematic literature review (SLR) synthesizes research on hands-on science education. Finding, evaluating, and synthesizing relevant studies is transparent in SLR. It reduces study selection bias and ensures a standardized review (Liberati et al., 2009). Numerous studies examine how hands-on activities affect science students' academic performance. Criterion-based inclusion and exclusion determined review scope. From 2000 to 2024, English-language peer-reviewed articles examined how hands-on science education affected academic success. We only considered empirical (experimental, quasi-experimental, observational) studies. Non-science, non-peer- reviewed, and academic success-free studies were excluded. Leaving out reports, dissertations, and non-peer-reviewed conference papers-maintained study quality (Furtak & Penuel, 2019).

Google Scholar, PubMed, ERIC, Scopus, and Web of Science for relevant studies were checked. The study searched "hands-on activities," "science education," "academic success," "active learning," and "learning outcomes" for articles. Both "AND" and "OR" operators found review- relevant studies. The study handsearched selected study references for relevant articles not in databases. Study screening and selection follow PRISMA flowchart. Relevance screening began with search-identified study titles and abstracts. Full-text articles were basis for inclusion and exclusion. Excluded studies were non-qualifying. Academic and practical data extraction. Fieldwork, lab experiments, project-based learning, and interactive simulations were examined. The evaluated grades, learning outcomes, and cognitive development. The participants' educational level, subject area (e.g., biology, physics, chemistry), and hands-on activity duration and frequency were considered during data extraction. Hands-on activities' effects on science education success were analyzed using extensive data extraction. The included studies were evaluated using reliability and validity criteria. After excluding articles that were not peer reviewed, the initial search yielded 156 articles. After removing duplicates and non-English studies, 104 articles were refined. Meticulous examination of the abstracts was conducted to ensure alignment with the review objectives, leading to the selection of 90 papers that primarily focused on scientific hands-on, excluding those that only marginally referenced them in broader discussions. To enhance the comprehensiveness of the review, this study expanded the search beyond Scopus by tracing the citations of selected papers in finance literature. Using Google Scholar's advanced search capabilities, this study identified additional studies cited by selected papers (Chen, 2022; Chen et al., 2020). This process yielded 13 new articles relevant to the focus, resulting in 103 papers included in this review. The studies' sample size, design, data collection methods, and valid and reliable assessment tools were considered. RCTs, well-designed quasi-experimental designs, and longitudinal studies improved causal relationships. Critical evaluation of selection and measurement biases in studies. This quality assessment considered the study's context to ensure the findings were applicable to other educational settings. Quality studies supported the review's conclusions (Miskiah et al., 2020).

The methodology is shown in Figure 1.

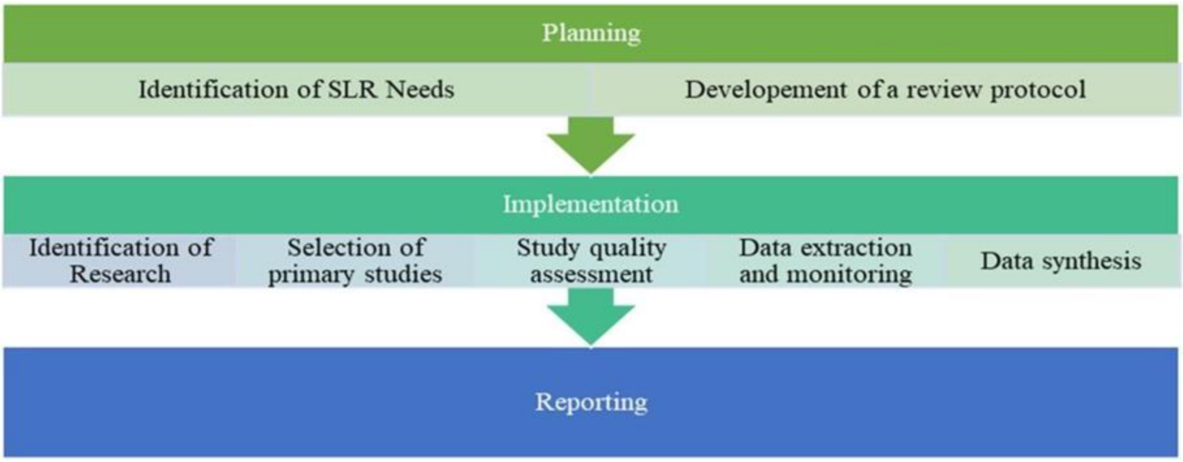

Figure 1. Systematic literature review (SLR) methodology.

Conceptual Framework

The conceptual framework for this study is how hands-on science activities affect academic success. Active and experiential learning theories let students grasp scientific concepts through hands-on activities. This framework discusses hands-on activities, their educational implications, and cognitive and non-cognitive academic success metrics. Activities with materials, tools, or phenomena teach science. These activities let students manipulate variables, observe results, and draw conclusions from firsthand experience. Hands-on activities include fieldwork, laboratory experiments, and using models like anatomical structures or molecular models to explain complex concepts. Combining theory and practice helps students understand science (Markowitz, 2004).

Grades, scores, and standardized tests measure student performance and academic success. Grades measure assignment and activity performance, while test scores measure structured assessment knowledge application. Hands-on activities boost critical thinking and problem-solving beyond these metrics. Experimental design requires students to hypothesize, analyze data, and evaluate results, which activates higher-order cognitive processes (Pine et al., 2006). Hands-on activities boost cognition, motivation, and collaboration. Activities like these make science learning enjoyable. Fieldwork group projects teach scientists teamwork and communication. Teachers can improve science education by using hands-on methods for different learning styles. Academic success depends on hands-on activities that develop cognitive and non-cognitive skills (Holstermann et al., 2010).

III. Results And Discussions

The systematic review included studies on how hands-on activities affect science education. Reflecting the global emphasis on experiential learning, these studies covered primary to tertiary education and diverse geographical contexts. Hands-on activities improve conceptual understanding, critical thinking, and scientific engagement, according to studies. Many studies examined how hands-on methods could help underrepresented or disadvantaged groups close science education achievement gaps (Freeman et al., 2014; Minner, 2010). Many studies relied on lab experiments. Organized labs outperformed lecture classes. Secondary school biology students who participated in inquiry-based experiments scored higher on knowledge retention and biological concept application post-tests. Laboratory experiments help students test hypotheses and draw conclusions, improving cognitive processing (De Jong et al., 2013). The included studies covered fieldwork and outdoor activities. Environmental science and geology, which require fieldwork, benefited most from these methods. Fieldwork boosted students' science and environmental awareness. Field trips improved spatial reasoning and geological formation interpretation in undergraduate geology students. It appears that contextual learning environmentsencourage genuine scientific inquiry (Kapici et al., 2019; Satterthwait, 2010; Taştan et al., 2018).

Studies showed that PBL promotes interdisciplinary skills, another major theme. PBL let students apply science to real-world problems. One study examined how PBL affects middle schoolers' renewable energy designs. Their communication, collaboration, and physics and engineering skills improved. These findings show that PBL improves science content and STEM transferable skills (Han et al., 2015; Yannier et al., 2021). Interactive simulations and digital tools show technology's role in science education, according to recent studies. Students had virtual hands-on experiences manipulating variables and observing results. Student performance in chemistry simulations using interactive software was comparable to those in traditional labs, suggesting that technology can supplement or replace physical hands-on activities in resource-constrained environments (Ornstein, 2006; Taştan et al., 2018). Despite their benefits, some studies found hands-on activities difficult to implement. Many issues included teacher training, resource availability, and time constraints within rigid curricula. A study in underfunded schools found that laboratory equipment and teacher expertise limited hands-on methods, which were effective. These findings suggest addressing systemic barriers to improve hands-on methods (Hofstein & Lunetta, 2004). Hands-on activities affected different student demographics in several studies. Results showed that hands-on methods helped disadvantaged students, who struggle in science. Interactive and inclusive learning reduced performance disparities and promoted education equity. An urban high school study found that hands-on projects improved academic performance and science self-efficacy, suggesting that experiential learning may reduce educational inequality (National Research Council, 2006).

Lapses in the literature included the need for longitudinal studies on hands-on activities' long-term effects. Most studies showed immediate academic improvements, but few showed long-term effects. Few studies have compared hands-on and flipped classrooms or collaborative learning. Filling these gaps may improve science teaching (Minner et al., 2010). Science education benefits from hands-on activities, according to this review. These approaches to theoretical problems promote active learning, critical thinking, and engagement. Effective implementation requires resources, teacher training, and curriculum support. Policymakers and educators should prioritisethese factors for hands-on learning (Freeman et al., 2014).

Themes Emerging from the Literature

The themes emerging from the literature on hands-on activities in science education reveal their profound and multifaceted impacts on students' learning experiences and outcomes. These themes include the enhancement of conceptual understanding, the promotion of critical thinking and problem-solving skills, and their significant influence on student motivation and engagement. Collectively, these dimensions underscore the value of hands-on activities as an integral component of effective science education.

Impact of Hands-on Activities on Conceptual Understanding

Practical activities help students understand science. Through materials, processes, and experiments, students apply theoretical concepts. Lectures and textbooks can make abstract concepts hard to understand. In contrast, hands-on learning helps students understand complex topics by seeing and touching scientific phenomena. Chemistry experiments demonstrate how combining substances affects chemical reactions better than static diagrams or verbal explanations. Freeman et al. (2014) found that active, hands-on learning improves conceptual assessments and knowledge application. Hands-on activities help kinesthetic and visual learners with auditory and textual instruction. When teaching force and motion, inclined planes or pendulums demonstrate Newton's laws. Putting learning into context improves comprehension. STEM fields build on foundational concepts, so this is crucial. Active engagement strengthens neural connections, making concepts easier to remember (Hofstein & Lunetta, 2004; Kirschner et al., 2006).

Role in Enhancing Critical Thinking and Problem-Solving Skills

Practical activities teach "learning by doing" and "learning by thinking." Students learn to think critically and solve problems by observing, hypothesizing, experimenting, analyzing data, and drawing conclusions using the scientific method. This fosters an analytical mindset by encouraging students to question assumptions, consider alternative explanations, and adjust their approaches based on evidence. Problem-solving in science education requires creativity, logic, and adaptability. Students must think critically and make decisions when designing environmental pollution or renewable energy experiments. Scientists identify variables, develop methods, and interpret results to solve problems. These activities improve reasoning by helping students critically evaluate data and recognize patterns, according to Prince (2004). Interactive activities help students solve real-world problems, enriching science education. By building prototypes for design challenges, engineering students learn science and prepare for real-world applications (Kolodner et al., 2003). Iterative learning through trial and error is key in hands-on activities. Scientific inquiry and beyond require resilience and adaptability, which this method teaches. Project-based learning models help students solve complex problems through critical thinking andcollaborative exploration, according to Trilling and Fadel (2009).

Influence on Student Motivation and Engagement

Hands-on activities motivate and engage students immediately. They create a dynamic, interactive classroom where students own their learning. Students often passively listen to theoretical teaching. Students become active learners with hands-on methods. Engagement is key to fostering science and curiosity. Learning is more meaningful and enjoyable with hands-on activities (Hofstein & Lunetta, 2004). Physics students gain confidence by building simple electric circuits. Play, exploration, and discovery motivate students, especially younger ones, in hands-on learning. This keeps disinterested or insecure science students engaged (Lepper et al., 2005). Hands-on activities improve classroom behavior and participation. Engaged students participate more in discussions and projects and are less disruptive. While teaching science, project-based learning like rocket design or volcanic eruption simulation engages students. Social hands-on activities enhance learning through peer interactions and teamwork (Chi, 2009).

Cumulative Benefits Across Themes

Hands-on activities enhance conceptual understanding, critical thinking, and engagement, enhancing comprehensive learning. These activities prepare students for scientific inquiry, problem-solving, and adaptability in higher education and the workplace. Experience builds resilience, creativity, and a lifelong love of discovery outside of science class. To maximize these benefits, educators and policymakers must address resource constraints, teacher training, and curriculum design to make science hands-on activities accessible and effective (Minner et al., 2010; Hmelo-Silver, 2007).

Comparison Across Different Contexts

The impact of hands-on activities in science education exhibits significant variation across different contexts, including age groups, geographic regions, and teaching methodologies. These contextual differences highlight the need to tailor hands-on learning strategies to suit specific learner demographics and environmental factors, ensuring optimal outcomes.

Variation Across Age Groups

Hands-on activities vary by age due to cognitive and developmental differences. Primary and middle schoolers learn motor and observational skills through tactile and visual activities. Building simple models, doing sensory experiments, and observing nature help younger students understand abstract science (Hofstein & Lunetta, 2004). Hands-on ecosystem learning helps elementary students retain and apply information better than lecture learning (Kirschner et al., 2006). Complex, inquiry-driven hands-on activities benefit older students, especially in high school and college. These students can think critically, test hypotheses, and collaborate. Chemistry and engineering design labs enhance conceptual understanding and advanced science readiness. Avoiding cognitive overload requires matching activity complexity to students' maturity and knowledge (Prince, 2004).

Geographic and Socioeconomic Variations

Geographic and socioeconomic factors affect hands-on activities because resources, infrastructure, and educators vary by region. Urban schools with resources often use modern scientific equipment, lab experiments, and simulations. These resources help students in such regions understand science, improving academic performance and STEM career interest (Minner et al., 2010). Lack of lab space, materials, and teacher training can make hands-on activities difficult in rural or underprivileged schools. Innovative methods like using locally available materials for experiments or incorporating traditional knowledge into science education have overcome these limitations. Even in poor countries, African and South Asian teachers have taught physics and biology with bottle caps, leaves, and sand (Kolodner et al., 2003).

Differences in Teaching Methodologies

Also important is how teaching methods affect hands-on activities. Traditional, teacher-centered approaches with occasional hands-on demonstrations may improve conceptual understanding but not critical thinking or problem-solving. Constructionist methods like inquiry-based and project- based learning make students active learners, maximizing the benefits of hands-on activities (Hmelo-Silver et al., 2007). In an inquiry-based framework, students design experiments, analyze results, and present findings to improve scientific understanding, collaboration, and communication. This method has increased scientific literacy and interest in various educational settings (Chi, 2009). Project-based learning, where students create eco-friendly solutions or studylocal environmental issues, boosts engagement and retention (Trilling & Fadel, 2009).

Intersection of Contextual Factors

These factors make hands-on activities harder. Geographic and socioeconomic factors may require age-specific strategies adjustment, and teaching methods must match resources. Low-income areas can benefit from project-based learning and community participation despite material constraints. Virtual labs and augmented reality experiments can give older students immersive STEM experiences in advanced education. Many contexts benefit from hands-on activities, but their success depends on adapting to learners' needs and environment. To be effective, hands-on scienceeducation must address contextual differences.

Challenges Identified in Implementation

Although proven effective, hands-on science education faces several obstacles that prevent its seamless integration into classrooms. Teachers struggle to provide engaging, practical learning due to resource constraints and pedagogical resistance. Insufficient materials, time, and teacher training hinder hands-on activities. Many low-income schools lack science labs, tools, and supplies for hands-on experiments (Hofstein & Lunetta, 2004). Uneven resource distribution hurts underprivileged schools. Teachers may use theoretical explanations instead of practical demonstrations in rural schools without lab kits. Timing is another important issue. Pressure to cover extensive curricula in short academic terms limits rich, activity-based learning. Hands-on activities are beneficial but require planning, execution, and discussion. This may discourage teachers from using such methods, especially in exam-driven systems that emphasize theory over practice (Abrahams & Millar, 2008). Hands-on activities need teacher training. Many teachers lack the confidence to design and lead complex experiments or technology-based activities. Underfunded or unavailable professional development programs prevent teachers from adopting innovative methods (Roehrig & Luft, 2004).

A second issue is educator, administrator, and stakeholder resistance to pedagogical change. Lecture-based teachers may be wary of hands-on activities due to classroom management, workload, or inefficacy. Resistance often stems from a lack of understanding of experiential learning's long-term benefits for students (Ertmer & Ottenbreit-Leftwich, 2010 School administrators and policymakers may increase resistance by not prioritizing or incentivizing hands-on methods. In systems that measure academic success by standardized test scores, stakeholders may prioritize exam preparation over hands-on activities (Hurd, 2000). Institutional and cultural norms influence pedagogical change attitudes. Some cultures view education as teacher authority and rote memorization. Student-centered, activity-based learning may challenge educators' and parents' beliefs (Crawford, 2000). These issues require multifaceted solutions. Affordable hands-on activities, educational infrastructure, and equitable resource allocation can reduce resource constraints. Low-cost experimental kits or virtual labs can help resource- constrained schools teach kids practically without much material (Finkelstein et al., 2005). To overcome change resistance, professional development programmes must emphasize skill-building, mindset shifts, and hands-on activities to improve long-term academic and cognitive outcomes. Policies that align assessment systems with experiential learning objectives can promote systemic education change by encouraging hands-on learning.

Implications of the Study

The implications of hands-on activities in science education span multiple levels, offering valuable insights for educators, policymakers, and researchers. By addressing the challenges and leveraging the opportunities presented by hands-on approaches, stakeholders can enhance the effectiveness of science education and its outcomes for learners.

Implications for Educators

Educators play a pivotal role in integrating hands-on activities into the curriculum. To maximize the benefits of such methods, teachers should adopt strategies that align with their students' developmental levels and learning needs. For younger students, simple, guided experiments or model-building activities can stimulate curiosity and foundational understanding. For older students, inquiry-based learning approaches, such as designing their experiments or solving real- world problems, can foster critical thinking and independence (Hofstein & Lunetta, 2004).Furthermore, educators should adopt interdisciplinary strategies, combining hands-on science activities with skills from other domains, such as mathematics, technology, and engineering, to reflect real-world applications. For instance, integrating coding into physics experiments or designing eco-friendly solutions in environmental science can enhance engagement and relevance (Prince, 2004). Collaborative projects that encourage peer-to-peer interaction and teamwork also promote deeper learning and improve communication skills, critical for professional development.

Policy Recommendations

At the policy level, significant changes are needed to support the effective implementation of hands-on activities in schools. One primary recommendation is the provision of adequate funding for resources, such as laboratory equipment, experimental kits, and digital tools like simulations and virtual labs. Equitable resource distribution is essential to ensure all students, regardless of geographic or socioeconomic status, have access to hands-on learning opportunities (Minner et al., 2010). Professional development programs for teachers should also be prioritized. Policymakers should invest in regular workshops, certifications, and peer-learning initiatives that equip educators with the necessary skills and confidence to facilitate hands-on activities. These programs should emphasize not only the technical aspects of conducting experiments but also the pedagogical approaches that maximize student engagement and learning outcomes (Roehrig & Luft, 2004). Assessment systems must evolve to reflect the value of experiential learning. By aligning assessments with hands-on activities—such as evaluating students' problem-solving processes, teamwork, and application of concepts—educators can emphasize the importance of active learning and reduce the focus on rote memorization (Ertmer & Ottenbreit-Leftwich, 2010).

Future Research Directions

While existing studies demonstrate the benefits of hands-on activities, there is a need for future research to address gaps in knowledge. Long-term studies examining the sustained impact of hands-on learning on academic performance, career choices, and scientific literacy are essential. For example, longitudinal studies tracking students who engaged in activity-based learning during their school years can provide insights into its influence on their professional and personal lives (Chi, 2009). Research should also explore the effectiveness of hands-on activities across diverse learning environments, including under-resourced schools, virtual classrooms, and inclusive education settings. For instance, studies could investigate how digital tools, such as augmented reality labs, can enhance hands-on learning for students with disabilities or those in remote areas (Finkelstein et al., 2005). Additionally, comparative studies across cultural and geographic contexts can reveal best practices and innovative adaptations that address local challenges while maximizing student outcomes. Another promising avenue for research is the integration of hands- on science education with emerging fields, such as sustainability and artificial intelligence. Investigating how experiential learning can prepare students for future challenges in these areas can guide curriculum development and policymaking, ensuring education remains relevant and forward-thinking (Hmelo-Silver et al., 2007).

IV. Conclusions

The conclusion is that hands-on science education boosts academic and cognitive performance. Studies show that these activities improve students' conceptual understanding, critical thinking, problem-solving, and engagement. Scientific principles are better understood through hands-on activities that apply theory to practice. Interactive and dynamic learning environments are essential for academic and professional development. Though proven effective, hands-on activities are hard to adopt. Time, materials, and trained teachers are still challenges in schools with limited budgets and infrastructure. In addition, educators and policymakers may resist change because they prefer traditional teaching methods for security. To improve student outcomes, educational authorities, schools, and teachers must rethink science education and emphasize hands-on learning. Science classroom hands-on activities need policy recommendations. To promote equitable experiential learning, fund lab equipment, teaching aids, and technology. Professional development programs should also empower teachers to use hands-on methods. Teacher training must emphasise hands- on activity technique and active learning and student-centered practices. Educational policies should align assessment systems with experiential learning outcomes to promote innovation.

References

[1] Areepattamannil, S. (2012). Effects Of Inquiry-Based Science Instruction On Science Achievement And Interest In Science: Evidence From Qatar. Journal Of Educational Research, 105(2), 134–146. Https://Doi.Org/10.1080/00220671.2010.533717

[2] Bhaduri, G., & Copeland, L. (2021). Going Green? How Skepticism And Information Transparency Influence Consumers' Brand

Evaluations For Familiar And Unfamiliar Brands. Journal OfFashion Marketing And Management, 25(1), 80–98. Https://Doi.Org/10.1108/Jfmm-08-2019-0175

[3] Brinson, J. R. (2015). Learning Outcome Achievement In Non-Traditional (Virtual And Remote) Versus Traditional (Hands-On) Laboratories: A Review Of The Empirical Research. Computers AndEducation, 87, 218–237. Https://Doi.Org/10.1016/J.Compedu.2015.07.003

[4] Chen, J. C. (2022). Developing A Cycle-Mode Poed Model And Using Scientific Inquiry For A Practice Activity To Improve Students' Learning Motivation, Learning Performance, And Hands- On Ability. Interactive Learning Environments, 30(7), 1252–1264. Https://Doi.Org/10.1080/10494820.2020.1716023

[5] Chen, J. C., Huang, Y., Lin, K. Y., Chang, Y. S., Lin, H. C., Lin, C. Y., & Hsiao, H. S. (2020). Developing A Hands-On Activity Using Virtual Reality To Help Students Learn By Doing. JournalOf Computer Assisted Learning, 36(1), 46–60. Https://Doi.Org/10.1111/Jcal.12389

[6] Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment Of Hands-On Stem Engagement Activities With Positive Stem Dispositions In Secondary School Students. Journal Of Science Education And Technology, 24(6), 898–909. Https://Doi.Org/10.1007/S10956-015-9572-6

[7] Corter, J. E., Esche, S. K., Chassapis, C., Ma, J., & Nickerson, J. V. (2011). Process And Learning Outcomes From Remotely-Operated, Simulated, And Hands-On Student Laboratories. ComputersAnd Education, 57(3), 2054–2067. Https://Doi.Org/10.1016/J.Compedu.2011.04.009

[8] Demirhan, E., & Şahin, F. (2021). The Effects Of Different Kinds Of Hands-On Modeling Activities On The Academic Achievement, Problem-Solving Skills, And Scientific Creativity Of Prospective Science Teachers. Research In Science Education, 51,1015–1033.Https://Doi.Org/10.1007/S11165-019-09874-0

[9] Ekmekci, A., & Gulacar, O. (2015). A Case Study For Comparing The Effectiveness Of A Computer Simulation And A Hands-On Activity On Learning Electric Circuits. Eurasia Journal Of Mathematics, Science And Technology Education, 11(4), 765–775. Https://Doi.Org/10.12973/Eurasia.2015.1438a

[10] Erickson, M., Marks, D., & Karcher, E. (2020). Characterizing Student Engagement With Hands- On, Problem-Based, And Lecture Activities In An Introductory College Course. Teaching And Learning Inquiry, 8(1), 138–153. Https://Doi.Org/10.20343/Teachlearninqu.8.1.10

[11] Furtak, E. M., & Penuel, W. R. (2019). Coming To Terms: Addressing The Persistence Of "Hands- On" And Other Reform Terminology In The Era Of Science As Practice. Science Education, 103(1),167–186. Https://Doi.Org/10.1002/Sce.21488

[12] Hampden-Thompson, G., & Bennett, J. (2013). Science Teaching And Learning Activities And Students' Engagement In Science. International Journal Of Science Education, 35(8), 1325–1343. Https://Doi.Org/10.1080/09500693.2011.608093

[13] Han, S., Capraro, R., & Capraro, M. M. (2015). How Science, Technology, Engineering, And Mathematics (Stem) Project-Based Learning (Pbl) Affects High, Middle, And Low AchieversDifferently: The Impact Of Student Factors On Achievement. International Journal Of ScienceAnd Mathematics Education, 13(5), 1089–1113. Https://Doi.Org/10.1007/S10763-014-9526-0

[14] Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-On Activities And Their Influence On Students' Interest. In Research In Science Education (Vol. 40, Issue 5, Pp. 743–757).Springer. Https://Doi.Org/10.1007/S11165-009-9142-0

[15] Hsiao, H. S., Chen, J. C., Lin, C. Y., Zhuo, P. W., & Lin, K. Y. (2019). Using 3d Printing Technology With Experiential Learning Strategies To Improve Preengineering Students' Comprehension Of Abstract Scientific Concepts And Hands-On Ability. Journal Of Computer Assisted Learning, 35(2), 178–187. Https://Doi.Org/10.1111/Jcal.12319

[16] Huppert, J., Lomask, S. M., & Lazarowitz, R. (2002). Computer Simulations In The High School: Students' Cognitive Stages, Science Process Skills And Academic Achievement In Microbiology.International Journal Of Science Education, 24(8), 803–821. Https://Doi.Org/10.1080/09500690110049150

[17] Kapici, H. O., Akcay, H., & De Jong, T. (2019). Using Hands-On And Virtual Laboratories Alone Or Together―Which Works Better For Acquiring Knowledge And Skills? Journal Of ScienceEducation And Technology, 28(3), 231–250. Https://Doi.Org/10.1007/S10956-018-9762-0

[18] Klahr, D., Triona, L. M., & Williams, C. (2007). Hands On What? The Relative Effectiveness Of Physical Versus Virtual Materials In An Engineering Design Project By Middle School Children.Journal Of Research In Science Teaching, 44(1), 183–203. Https://Doi.Org/10.1002/Tea.20152

[19] Knox, K. L., Moynihan, J. A., & Markowitz, D. G. (2003). Evaluation Of Short-Term Impact Of AHigh School Summer Science Program On Students' Perceived Knowledge And Skills.Journal Of Science Education And Technology, 12(4), 471–478. Https://Doi.Org/10.1023/B:Jost.0000006306.97336.C5

[20] Markowitz, D. G. (2004). Evaluation Of The Long-Term Impact Of A University High School Summer Science Program On Students' Interest And Perceived Abilities In Science. Journal Of Science Education And Technology, 13(3), 395–407. Https://Doi.Org/10.1023/B:Jost.0000045467.67907.7b

[21] Mccarthy, C. B. (2005). Effects Of Thematic-Based, Hands-On Science Teaching Versus A Textbook Approach For Students With Disabilities. Journal Of Research In Science Teaching, 42(3), 245–263. Https://Doi.Org/10.1002/Tea.20057

[22] Miskiah, Suryono, Y., & Sudrajat, A. (2020). The Effects Of Blended Learning On Elementary School Students' Creativity And Activeness. Universal Journal Of Educational Research, 8(9), 3958–3964. Https://Doi.Org/10.13189/Ujer.2020.080920

[23] Ornstein, A. (2006). The Frequency Of Hands-On Experimentation And Student Attitudes Toward Science: A Statistically Significant Relation (2005-51-Ornstein). Journal Of Science EducationAnd Technology, 15(3–4), 285–297. Https://Doi.Org/10.1007/S10956-006-9015-5

[24] Pine, J., Aschbacher, P., Roth, E., Jones, M., Mcphee, C., Martin, C., Phelps, S., Kyle, T., & Foley, B. (2006). Fifth Graders' Science Inquiry Abilities: A Comparative Study Of Students In Hands- On And Textbook Curricula. Journal Of Research In Science Teaching, 43(5), 467–484.Https://Doi.Org/10.1002/Tea.20140

[25] Satterthwait, D. (2010). Why Are 'Hands-On' Science Activities So Effective For Student Learning?Teaching Science, 56(2), 7–10. Https://Search.Ebscohost.Com/Login.Aspx?Direct=True&Profile=Ehost&Scope=Site&Authtype= Crawler&Jrnl=14496313&An=52539907&H=U2zzom%2fge1zmu6btcjq3oksydwvszt Ydidbxuviny3fzjfkmb0rougs%2bx%2bm5ixgwzovqmfsnza%2fz9gohaubaua %3d%3d&Crl=C

[26] Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects Of Active-Learning Experiences On Achievement, Attitudes, And Behaviors In High School Biology. Journal Of Research In Science Teaching, 44(7), 960–979. Https://Doi.Org/10.1002/Tea.20183

[27] Taştan, S. B., Davoudi, S. M. M., Masalimova, A. R., Bersanov, A. S., Kurbanov, R. A., Boiarchuk, A. V., & Pavlushin, A. A. (2018). The Impacts Of Teacher's Efficacy And Motivation On Student's Academic Achievement In Science Education Among Secondary And High School Students. Eurasia Journal Of Mathematics, Science And Technology Education, 14(6), 2353–2366.

Https://Doi.Org/10.29333/Ejmste/89579

[28] Walan, S. (2019). Teaching Children Science Through Storytelling Combined With Hands-On Activities–A Successful Instructional Strategy? Education 3-13, 47(1), 34–46. Https://Doi.Org/10.1080/03004279.2017.1386228

[29] Yannier, N., Hudson, S. E., Koedinger, K. R., Hirsh-Pasek, K., Golinkoff, R. M., Munakata, Y., Doebel, S., Schwartz, D. L., Deslauriers, L., Mccarty, L., Callaghan, K., Theobald, E. J., Freeman, S., Cooper, K. M., & Brownell, S. E. (2021). Active Learning: "Hands-On" Meets "Minds-On." Science, 374(6563), 26–30. Https://Doi.Org/10.1126/Science.Abj9957

[30] Yilmaz, M., Ren, J., Custer, S., & Coleman, J. (2010). Hands-On Summer Camp To Attract K-12 Students To Engineering Fields. Ieee Transactions On Education, 53(1), 144–151.Https://Doi.Org/10.1109/Te.2009.2026366