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The Impact of Science Practical Work on Secondary School Students' Learning Outcomes: A Meta-Analysis

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Abstract: This meta-analysis appraises the impact of practical science work on the learning outcomes of secondary school students based on 16 recent publications based on a quasi-experimental design. The research includes cognitive, affective, and psychomotor domains and compares the performance of students who have been subjected to practical science teaching to those who have been subjected to theoretical teaching. The search of the Scopus, ERIC, and DOAJ databases, adhering to strict inclusion criteria, allowed the definition of quantitative studies used in the meta-analytic procedures. Heterogeneity (I^2 = 94.43 %) was significant, and a random-effects model was adopted with standardized effect sizes determined using Hedges g. This finding has a high general effect (g = 1.15), indicating that practical science work has a significant impact on learning in different contexts. The implementation quality, teacher competence, and resource availability were inconsistent across all the studies, yet the results were quite the same, stating the clear advantage of the experiential, inquiry-based methods of implementation. Heterogeneity diagnostics indicate actual rather than random errors and evidence of limited publication bias, as portrayed by funnel plots. The meta-analysis confirms the pedagogical worth of practical science work and its utilization in curricula, notably in coordination with properly established instructional objectives, as well as in the provision of proper teacher training and infrastructure. These results provide evidence-based policy recommendations for both policymakers and teachers to enhance science education through effective hands-on practices.

Keywords: Experimental Learning, Meta-analysis, Science Practical Work, Secondary Education, Student Learning Outcomes.
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Introduction

Teaching and learning strategies in the 21st-century learning center have shifted to a different focus, one that is not quite the traditional didactic approach but rather strategies that foster critical thinking, creativity, collaborative efforts, and problem-solving skills. Also known as 21st-century skills, these competencies play a crucial role in equipping students with the essential abilities and skills necessary to navigate complex situations in real life and become engaged members of a knowledge-based society (Drigas & Mitsea, 2021). In this context, science education plays a pivotal role in imparting to students not only theoretical knowledge but also practical skills and an understanding of science. More specifically, the development of critical thinking has emerged as one of the pillar objectives of science teaching. Critical thinking enables students to analyze, assess, and synthesize information, draw logical conclusions, and make informed decisions (Akumaa & Callaghan, 2019). However, to accomplish these educational goals, it takes more than just reading a book. It employs an instructional strategy that involves students in the scientific process. These strategies include incorporating practical scientific work into the curriculum.

Science practical work refers to laboratory work, demonstration work, simulations, and other types of investigative work in which students can work directly with scientific phenomena (Nguru, 2021). This enables students to introduce scientific approaches, hypothesis testing, reactions, variable measurement, and result interpretation within a confined setup. Its pedagogical rationale is based on constructivist learning theories, which assume that knowledge is actively created through practice combined with reflection (Chen, 2024). Practical classes enable students to reinforce the theoretical knowledge they acquired prior to the practical and develop the procedural and metacognitive skills necessary for scientific investigation. This element of experiential learning is particularly desirable in secondary schools, where learners are transitioning to more abstract thinking and greatly benefit from being placed in context-rich, inquiry-based learning environments.

Several empirical studies have discussed the importance of practical science work in enhancing students' cognitive outcomes, including conceptual knowledge and problem-solving abilities, as well as affective outcomes, such as motivation, interest, and scientific attitudes (Shana & Abulibdeh, 2020; Twahirwa & Twizeyimana, 2020). In addition, practical work contributes to the development of higher order thinking skills, as shown in the revised taxonomy of Bloom, which lists application, analysis, synthesis, and evaluation as primary mental processes (Putra et al., 2021). In real-life contexts, students often hypothesize, formulate procedures, gather and interpret data, and present arguments supporting their findings, which contributes to their critical thinking and scientific literacy (Hamid et al., 2023; Manishimwe et al., 2023). These skills are not only prerequisites for academic excellence but also for informed citizenship in a science-driven world.

Although it has much potential, the effectiveness of practical science work in meeting students' learning outcomes is debatable. Some studies document substantial positive effects but note that the benefits are small or irregular and that implementation challenges are usually the origin of these drawbacks (Oliveira & Bonito, 2023). Examples include laboratory experiences being of little educational value due to poorly designed practical activities, a lack of clear objectives, inadequate resources, and insufficient teacher training. In practice, there is sometimes a reduction of work to a dry mechanical process that lacks inquiry, critical thinking, and conceptual connection, therefore not meeting the educational objectives (Chuene & Teane, 2024). Moreover, there are differences in educational contexts, such as variations in curriculum, school resources, classes, and teacher expertise, which can exacerbate the applicability of research results.

The problem is compounded in developing countries, such as overcrowded classrooms, inadequate laboratory infrastructure, and a lack of professional development opportunities for science teachers. Thus, the national curriculum requires scientific practical work, but its introduction to students is, as a rule, either superficial or inconsistent (Chala & Walabu, 2019). This gap between policy and practice presents a compelling argument for the necessity of evidence-based approaches to ensure effective implementation of practical work in science education. It is worth noting that extensive testing of students in secondary schools has consistently shown poor performance in the areas of scientific reasoning and critical thinking, with some students failing to reach proficiency in standardized assessments (Kibirige, 2020). These results are a sobering reminder that instruction needs to be developed that is both pedagogically and practically sound.

Most literature on practical science work relies on small-scale experimental or quasi-experimental studies. Although such studies are informative, they tend to be narrow in scope and context-based, making it difficult to draw generalizable conclusions from them. Several systematic reviews and narrative syntheses have attempted to summarize the evidence; however, few have employed meta-analytic methods to quantify the size of the effects across studies and obtain an estimate of the magnitude of the impact (Oliveira & Bonito, 2023). A meta-analysis is a powerful statistical tool that combines the outcomes of several studies, considers differences in sample size, and yields general effect measures with confidence intervals. Such a method enables researchers to establish specific patterns, introduce tests of moderating variables, and draw more sound conclusions than an individual study.

Against this background, a meta-analysis of the effects of practical science work on the learning outcomes of secondary students is vital. It is particularly timely that such an analysis emerges at a moment when data-informed educational policy is becoming increasingly pressing and when there is a growing need to find scalable and practical approaches to instruction in the field. Furthermore, as developments in pedagogical practice, technology use in education, and curriculum design have changed dramatically over the past few years, it is essential to consider research studies that have been published in the past five years to ensure that the findings apply to the current state of education. The current study fills this gap by conducting a systematic review and statistical synthesis of recent empirical studies on the impact of practical science work on secondary school students' learning outcomes. The outcomes analyzed were cognitive (e.g., test scores, conceptual understanding), affective (e.g., interest and motivation), and psychomotor (e.g., laboratory skills, procedural knowledge) outcomes. It is also worth considering the possible moderating variables, including the subject domain (biology, chemistry, physics), the format of the practical work (hands-on, virtual, demonstration), the length of the intervention, and the region. The current meta-analysis aims to address the following research question: What is the general impact of science practical work on the learning of secondary school students?

This study has three expected contributions. First, it will provide educators and those involved in curriculum development with empirical data on the effectiveness of practical science work, thereby aiding instructional decisions that promote meaningful learning. Second, it will contribute to the design of teacher training programs by defining best practices and frequent weaknesses in administering practical activities. Third, it will provide policymakers with fact-based clarification on how they can advance science education policies, especially in resource-limited settings. On a larger scale, this study complements the argument that experience- and inquiry-based learning are the core of contemporary pedagogy and that students are not mere consumers of knowledge but builders.

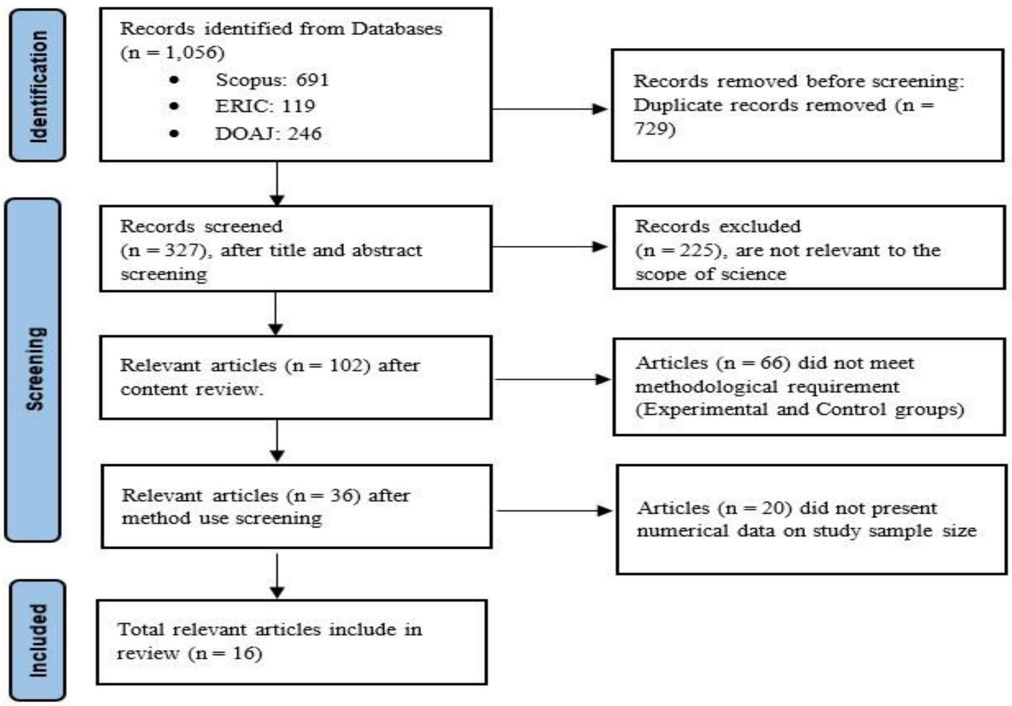
Practical science work is a crucial element of effective science education that can contribute to improved student learning at various levels. However, to achieve this potential, one must understand what works, with whom it works, and the conditions under which it occurs. This study aims to address a significant gap in literature, primarily through a thorough meta-analysis of recent studies and contributes to the further development of evidence-based science-education pedagogy in secondary school education.

Methods

The methodological procedures of this meta-analysis were carried out following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Figure 1 provides a visual representation of the identification, screening, eligibility, and inclusion process.

Figure 1

PRISMA Flowchart



The PRISMA flow chart diagrammatically illustrates the steps followed to identify, screen, and enrol studies in this review. A total of 1,056 records were identified in three databases: Scopus (691), ERIC (119), and DOAJ (246) in the first search. A total of 729 duplicates were removed in the second deduplication Step, and 327 records were screened for titles and abstracts. In this way, 225 articles were discarded because they were not in the sphere of science. The remaining 102 full-text articles were then sent to the next stage, the methodological evaluation, and 66 records were rejected because they did not have the required experimental and control groups. The remaining 36 articles were then evaluated in terms of methodological rigour. At this point, another 20 studies were omitted as they did not provide numeric data on the size of the studies. Finally, 16 articles were selected that met all the inclusion criteria and provided sufficient information for the analysis.

The methodology of the study involves a meta-analysis, utilizing a quantitative descriptive study design to summarize the results of past research on the effectiveness of practical science on secondary school students' learning outcomes. The group contrast method of meta-analysis was applied to determine and analyze the disparities between the learning outcomes achieved in a science learning setting and those achieved through typical teaching approaches. Following the meta-analytic procedure, this study produced an empirical generalization by aggregating the results of various studies that shared similar attributes using statistical means of analysis.

The meta-analysis involved systematic collection, appraisal, and analysis of data from primary studies that met the specified inclusion criteria (Sousa-Pinto & Azevedo, 2019). To cover peer-reviewed, high-quality, and open-access literature broadly, a thorough search of the most significant academic databases, Scopus, ERIC, and DOAJ, was conducted for journal articles on the topic. The articles were limited to those published within the past five years (2020-2025), as the information obtained was intended to align with current trends and recent developments in science education. The keywords used in the search were a combination of terms, including science practical work, learning outcomes, secondary schools, and experimental design. The search results were refined using Boolean operators (AND, OR) to increase precision. As shown in Figure 1, articles were screened based on predefined inclusion and exclusion criteria, summarized in Table 1

Table 1

Eligibility Criteria for Article Inclusion

Criterion	Inclusion	Exclusion
Article Type	Peer-reviewed journal articles	Non-journal sources (e.g., conference papers, theses, book chapters)
Journal Source	Indexed in Scopus, ERIC, or DOAJ	Sources not indexed in Scopus, ERIC, or DOAJ
Publication Period	2020–2025	Published before 2020
Accessibility	Open access (freely available)	Paywalled or inaccessible articles
Study Focus	Examines the impact of science practical work on student learning outcomes	Studies on unrelated pedagogical methods or unrelated subjects
Research Method	A quasi-experimental design with experimental and control groups	Other research designs (e.g., qualitative studies, case studies, surveys)
Data Reporting	Includes quantitative data: sample size, means, and standard deviations	Missing or incomplete statistical data
Educational Level	Secondary Schools	Higher education (college/university level) or informal education

Journal articles were preferred because of their strict peer-review process, which provides a high level of reliability and scientific validity. The use of open-access sources was an effort to facilitate transparency and enable other researchers to conduct similar studies in the future. This selection was restricted to research that used quasi-experimental treatments with a control group involved, as it would enable methodological consistency and facilitate sound comparison results.

After selection, all articles were manually coded. The coding process involved extracting pertinent information, such as the author's name, year of publication, sample size, and the mean and standard deviation for each group. The data was tabulated and systematically arranged in a coding matrix. The entries were checked by two independent reviewers to ensure validity and consistency, inter-rater reliability was calculated using Cohen's Kappa ($\kappa = 0.82$), which indicates strong agreement. and ambiguous or unclear results were removed. This procedure enhanced the validity of the coding process and reduced potential bias.

To ensure analytical rigour, a random-effects model was employed in the meta-analysis conducted in this study. It assumes that the effect sizes of the studies cannot be compared with each other, as they do not follow the same distribution but rather exhibit a distribution indicating possible heterogeneity of contexts (variation in the implementation of practical work, instruction settings, and sample populations). One of the conditions for applying the random-effects model is moderate-to-high heterogeneity, which is determined using the I^2 statistics. In case $I^2 >$ 25 %, non-trivial heterogeneity should be assumed, and a random-effects approach should be used (Kanters, 2022). The analysis was performed using the SPSS software. Because the learning outcome data provided by the studies were on different scales (e.g.0-10,0-100), the effect sizes were standardized using Hedges g. This measure controls for slight sample bias and provides a direct basis for comparing the studies. The Hedge's g formula involves pooled standard deviations and sample sizes to determine the standardized difference between the means of the experimental and control conditions.

The SPSS output included a list of outputs, including a forest plot that provided a pictorial image of effect sizes, confidence intervals, and standard errors in the studies. A funnel plot was generated to identify any possible publication bias, which could occur if smaller studies with no statistically significant findings were underrepresented. Heterogeneity statistics, including I^2, Q-statistics, and p-values, were reported to determine between-study heterogeneity. Finally, the overall effect size was used to represent the aggregate level of influence of science practical work on students' learning outcomes in secondary schools. This methodological procedure ensured the reliability and validity of the results, providing sound evidence of the usefulness of practical science work in enhancing the learning performance of secondary school students. The arbitration of open selection criteria, a rigorous screening process, and general statistical methodology helped reduce bias and facilitate the replication of this meta-analytic study.

Results

This review examined 16 research studies that fulfilled the predetermined inclusion criteria. This analysis aimed to investigate the impact of practical science work on secondary school students' learning outcomes. All the chosen studies contained quantitative data revealing the differences in learning outcomes between groups exposed to practical science activities and those taught with more traditional instructional methods based on theory rather than practice. Effect sizes and standard errors were computed using reported sample sizes, mean values, and standard deviations. Table 2 presents a detailed description of the sample data and statistical results of each study.

Table 2

Summary of Research Data, Sample Size, Standard Deviation, Effect Sizes, and Standard Errors.

Code	Author	Practical Work (Experimental)			Conventional (Control)			Hedges' g (ESg)	Standard Error (SEg)
		n	M	SD	n	M	SD		
P1	Shana & Abulibdeh (2020)	49	27.08	1.038	49	17.30	4.99	2.688	0.279
P2	Twahirwa & Twizeyimana (2020)	60	13.13	3.10	60	10.03	2.38	1.115	0.196
P3	Ponnusamy et al., (2022)	60	31.61	2.44	60	26.88	2.52	1.895	0.220
P4	Kibirige, (2021)	30	22.8	6.50	30	11.3	3.00	2.242	0.329
P5	Ojo & Owolabi, (2020)	20	44.65	5.12	30	17.70	3.53	6.269	0.690
P6	Khan et al., (2022)	40	73.50	7.72	40	44.02	8.01	3.711	0.369
P7	(Nguru, 2021)	55	80.16	6.60	55	67.9	24.90	0.668	0.196
P8	Kelkay & Sitotaw, (2022)	59	6.75	1.39	59	4.10	1.61	1.751	0.217
P9	Afyusisye & Gakuba, (2022)	46	55.33	22.38	46	47.15	17.95	0.400	0.211
P10	Mneji et al., (2024)	108	10.72	4.38	111	9.6	2.20	0.323	0.136
P11	Sanptul et al. (2022)	88	0.60	0.19	77	0.36	0.19	1.257	0.171
P12	Yolanda (2020)	37	42.16	13.72	37	35.27	11.90	0.531	0.237
P13	Njaputro et al. (2020)	22	57.77	2.81	22	48.27	2.80	3.326	0.465
P14	Qaqbal & Emodin (2023)	77	25.29	5.06	72	20.75	6.22	0.799	0.170
P15	Priyodis et al. (2021)	25	78.16	7.12	24	59.33	9.64	2.193	0.362
P16	Kahyani et al. (2023)	30	83.61	7.05	30	80.83	6.40	0.408	0.261

Note:

M: Mean of each research sample data.

n: Number of samples in the research data.

SD: Standard deviation of the research sample.

ESg: Effect size as an index used to summarize the results of the meta-analysis.

SEg: Standard error used to determine the actual effect interval.

The current meta-analysis used a random-effects model to account for the fact that the studies included in the review differed significantly in terms of sample size, setting of implementations, and the degree to which their work was conducted in good faith. The findings of the heterogeneity test supported this decision, and the results are reported in Table 3.

Table 3

Heterogeneity Analysis Results

Statistic	Value
Q-statistic	269.20
df (Q)	15
p-value (Q)	< 0.001
I^2 (%)	94.43%

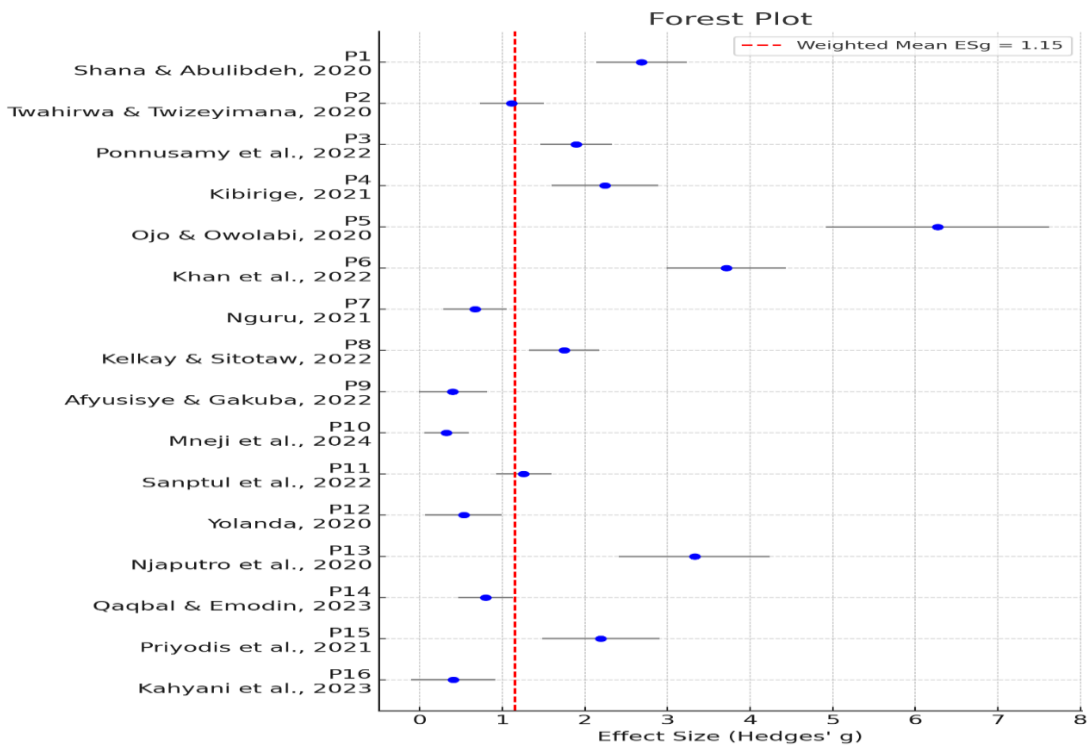
The Q-statistics were 269.20, the degrees of freedom were 15, and the p-value was < 0.001. The results of this study show that the heterogeneity of effect sizes that occurred between the different studies was not random and, therefore, not likely to be due to sampling errors, thus establishing the existence of real heterogeneity. The complementary statistics show that all the variation due to heterogeneity and not to chance is 94.43 %. This value greatly exceeded the standard value of 25 %, demonstrating that the random-effects model was appropriate. The H^2 index, which is a measure of total variability divided by sampling variability, was also greater than one, indicating that the observed dispersion was indeed large and not due to chance. Overall, these statistical measures presuppose that various educational settings, teaching quality, and teacher competence play roles in effect size heterogeneity.

The pooled weighted mean effect size (Hedges g) was also 1.15, which significantly surpassed the effect size (Cohen) criterion according to the norm of large effect size. This finding confirms that students who were involved in science practical activities scored higher than those who were subjected to the traditional methods of teaching science. Figure 2 provides a view of the forest plot that originated from a single study and its related effect sizes, as well as the 95 per cent confidence intervals of the studies, with each square depicting the effect size associated with an individual study. In contrast, the horizontal lines correspond to the confidence intervals. The red dashed line indicates the direction and magnitude of the pooled effects.

Despite the observable inconsistency of specific results, the overall confidence interval of the pooled effect size output was between 0.15 and 1.5, which effectively ruled out a zero value and achieved a statistically significant result. Thus, even under conditions of heterogeneity, practical scientific work always has positive outcomes. This result is supported by the findings of other researchers, such as (Shana and Abulibdeh (2020) and Twahirwa and Twizeyimana (2020), who also showed that structured and high-support practical tasks can significantly contribute to enhancing students' cognitive and procedural learning outcomes. The apparent heterogeneity is a consequence of the differences in implementation quality, teacher skills, and resource availability, as opposed to the lack of an effect.

Figure 2

Forest Plot



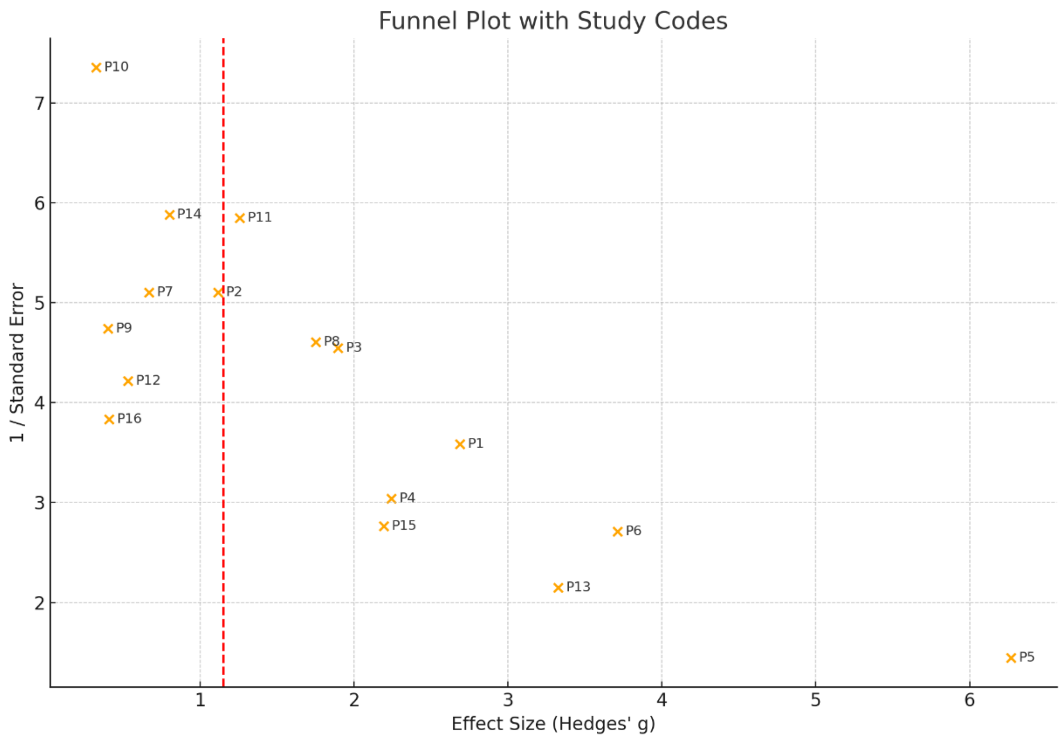
Beyond what is learned about effect size, potential moderating variables add additional nuances to the findings. For instance, gains in biology were generally higher than those in physics or chemistry, perhaps because biological experiments could be performed more easily with limited resources. Additionally, interventions that involved more active, hands-on interaction tended to have larger effects than those that were more demonstration-based or virtual, highlighting the importance of active engagement. Although the number of studies in each subgroup was limited and the statistical power for formal moderation tests was low, we found descriptive trends indicating that subject domain, instructional format, duration of intervention, and regional context had a significant impact on outcomes. Therefore, future research should consider larger samples in a variety of settings to enable more powerful moderator analyses.

A funnel plot was created to determine the potential publication bias (Figure 3). The symmetry identified during the visual inspection of the plot suggests that studies with insignificant findings and small samples were not systematically excluded. The funnel plot is shown in Figure 3.

The funnel plot constructed in Figure 3 strengthens our meta-analysis. Every point on the graph indicates single research, the x-axis indicates Hedging g, and the y-axis is 1/SE, which measures precision. Studies that used larger samples are located at the top of the plot and vice versa. The red dashed vertical line represents the random-effects pooled estimate (Hedges g = 1.15).

Figure 3

Funnel Plot



Interestingly, studies seem to be distributed asymmetrically, which may indicate the possible presence of publication bias or small study effects. Some papers P5 (Ojo & Owolabi, 2020) and P6 (Khan et al., 2022)) are on the lower and right sides, where the effect size is significant and precision is restricted due to small sample sizes. In contrast, P10 (Mneji et al., 2024) and P11 (Sanptul et al., 2022), which are closer to the upper position, have high precision and remain closer to the pooled estimate. This asymmetry further illustrates one of the most common associations of publication bias: studies of lower magnitude observe more radical effects.

The data visual spread in the funnel plot confirmed the significant heterogeneity reported in the previous analysis (I^2 = 94.43 %). As a group, these trends indicate that the variation in the studies is not accidental but rather an indication of substantive variation in the designs, implementation fidelity, and contextual issues of resources and teacher competency. Therefore, understanding the overall impact of effective practical work with science on students' achievement requires attention to both statistical and methodological diversity.

In addition to heterogeneity, there are two potential sources of bias that may impact the generalisability of the findings. First, most of the included studies came from developing countries, particularly within Africa. While this is valuable in terms of understanding low-resource educational contexts, it may undermine the extent to which the findings are applicable to high-income contexts where infrastructures, modes of teaching, and policy contexts differ. Second, the use of open-access sources might have led to publication bias as studies that were published in a subscription-based setting were excluded, and these studies might be systematically different from the open-access ones in terms of their findings. These limitations imply that, although the results are highly relevant for resource-constrained settings, great caution should be taken in generalising them beyond.

Sixteen articles were reviewed. The mean effect size was 1.15, indicating a moderate positive effect of practical science work on students' learning outcomes. The heterogeneity was substantial ($I^2 = 94.43$ %), and therefore, the use of the random-effects model was reasonable. These findings imply that practical science work is broadly successful in boosting student learning results at the secondary school level, although its effect depends on the context. Rigorous implementation, educator attention, and curriculum organization are essential elements that mediate the achievement of practical science teaching. When designed and implemented correctly, practical work becomes a significant, inquiry-based approach to instruction, with higher student engagement and productivity in science education.

Discussions

Science practical work as an instructional strategy has garnered significant support in recent years for its potential to enhance students' learning outcomes. The applied aspect of practical work in science emphasizes active interaction with the material, personalized learning, and its practical application in everyday life (Nguru, 2021). These views are supported by the results of this meta-analysis, which show that such improvements in student progress are possible through practical science activities and that these improvements can be substantial in terms of geometric enhancements in students' understanding of scientific phenomena and the development of their critical thinking abilities.

The difference in the impact of science practical work is expected to be consistent with the literature. For example, Atchia and Rumjaun (2023) noted that incorporating contextual and technological improvements into the learning process positively impacted student learning outcomes. Analogously, science practice can also be scaled up by placing it in focal settings, coupling it with digital technologies, or positioning point-shooting activities. These tactics encourage more engagement and learning, particularly when students are allowed to plan experiments independently, collect data, and analyze them.

According to Taale and Mahamadu (2023), allowing students to solve problems independently rather than having them work in groups increases their learning autonomy and intrinsic motivation. Such a principle can be applied in the context of working practice when students are exposed to real-world phenomena to gain firsthand experience and apply the theoretical knowledge they have acquired by critically comparing the results. The mean effect size of 1.15 in this study indicates that practical science teaching can lead to a significant improvement in learning outcomes, which is consistent with the earlier argument that student-centred learning environments facilitate deeper cognitive development (Mkimbili & Kayima, 2022).

The potential contribution of practical science work is to support significant learning, which is one of its most significant strengths. According to Taale and Mahamadu (2023), meaningful learning is characterized by students' ability to relate new information to old information in a personal and relevant way. Science practical activities create an excellent environment for facilitating such learning, allowing students to manipulate variables, make predictions, test their hypotheses, and experience the direct impact of a scientific theory at work. With the help of a culturally appropriate setting, including an experiment founded on a local phenomenon or natural resources, practical work can be both informative and transformative.

Practical work also contributes to the improvement of collaboration and creativity, which are important elements of 21st-century learning (Nneji et al., 2024). Through group investigations, students learn how to delegate roles, negotiate group experiments, and draw conclusions as a group. This is also representative of the work of science and prepares students to work in teams in the fields of science and technology. Additionally, with a well-defined and rational framework of inquiry constructs, as Margolis (2020) suggests, practical tasks can serve as scaffolding tools to support student learning and promote an orderly approach to problem-solving.

The identified results confirm that critical thinking is promoted by well-developed practical work. Works like those of Ponnusamy et al. (2022) point out that students have tentative knowledge but are also trained in the skills of analysis, evaluation, ion, and information generation with these principles; practical work helps bridge the gap between abstract theory and practical experience, thereby deepening knowledge and facilitating memorization. Nevertheless, it was also found that a significant degree of heterogeneity exists among the studies included in the meta-analysis, as indicated by a high I^2 (%) indices (I^2 = 94.43 %). This inconsistency indicates that the success rate of the work is largely contextual. Institutional and student backgrounds, teacher competence, quality of instruction, and availability of laboratory resources are all factors that impact the effectiveness of practical science teaching. Such constraints reduce learners' capacity to participate actively in hands-on activities, thereby limiting possible knowledge acquisition. Another limitation of this meta-analysis is that it only included quantitative quasi-experimental studies in order to calculate standardised effect sizes. While this methodological choice was appropriate for statistical synthesis, it ignored rich qualitative evidence that could explain contextual variables, teacher practices, and student experiences. Future well-designed systematic reviews or mixed-methods approaches should combine quantitative and qualitative studies in order to better develop an understanding of how and why real-world science work affects student learning outcomes.

This result is consistent with Colton et al. 's (2020) study, which mentioned that even collaborative conditions could not lead to learning improvement when students only split assignments instead of synthesizing concepts due to a lack of conceptual synthesis. Again, this practical work is procedural and not cognitive, and therefore, there is a discreet development of critical thinking. According to Acharya and Subedi (2023), the teacher's role is essential in more than just presenting information but also in reflection, confirmation of the meaning of what the student has learned and encouraging further exploration.

Moreover, Rodgers (2022) revealed that engaging in practical work helps build scientific communication, specifically when students are required to report their findings, substantiate their conclusions, or suggest ways to enhance them. Nevertheless, certain drawbacks remain in the practical application of this approach. The limited sample size, research design, and context-specific implementations hinder the possibility of drawing general conclusions from the results.

Additionally, Shagufta Rafique et al. (2024) posited that practical work needs to be customized to suit various student intelligence and learning preferences; hence, there is a need for flexible and differentiated instruction.

Teachers play a central role in the optimization of practical science and content knowledge, enabling them to control inquiry-based labs, conduct reflective conversations, and evaluate students' understanding of conceptions. Colton et al. (2020) provide another example of how practical work can be connected to a real-life setting. When teachers framed practical activities related to disaster mitigation, students not only gained scientific knowledge but also became more aware of the issues and needs of the community.

In the future, teachers’ professional development and curricula materials that facilitate the most effective practices in realistic science teaching should be provided. Moreover, further research should prioritize how technological tools, including simulations, data-logging software, and virtual laboratories, can complement hands-on experiments, particularly in resource-starved schools. It turns out that practical science work is not simply one way of confirming scientific laws but the essence of science as a process. Students have opted to learn science and experience it in a way that has never been truer through experimentation, observation, and the use of evidence to conclude. Practical work is not just content reinforcing; it is also a way of fostering the desired skills, particularly those essential in the 21st century, such as critical thinking, collaboration, creativity, and effective communication. According to Putra et al. (2021), the methods used in education that enable students to question, experiment with their ideas, and construct their knowledge are aligned with the ideals of contemporary teaching.

While the technical aspects of meta-analysis are important for academic rigor, it is equally important to communicate the results of the meta-analysis in a way that is accessible to practitioners. This review demonstrates that when science activities are well designed, they can be highly effective in enhancing student learning outcomes in the cognitive, affective, and psychomotor domains when integrated well into curricular goals and objectives. This bodes well for teachers, as much as it is practicable, putting aside resources, it is likely that putting in the effort to design enquiry-based lab sessions will lead to measurable change in terms of student engagement and achievement. The findings for curriculum developers suggest that practical components in curricula must be incorporated in a systematic way as opposed to additions. The evidence indicates that policymakers, especially in low-resource settings, can be justified in focusing on teacher training, laboratory infrastructure, and professional development. By contextualising findings, this study tries to address the gap between research and practice, making the knowledge useful for those who are most directly involved in implementation in the classroom.

In summary, the meta-analysis confirmed the significant influence of practical science work on study outcomes among secondary education learners. This is because, although the results will vary depending on the quality of implementation and circumstantial factors, the overall impact will be beneficial. Practical work can be an essential element in effective science teaching, provided it is accompanied by planned preparation, supportive infrastructure, and pedagogical support. It provides a strong platform to develop not only academic knowledge but also the competencies required by students to contribute to lifelong learning in a complex and changing world.

Conclusion

The findings of this meta-analysis confirm that practical science work positively impacts students' learning outcomes in secondary schools. A universal trend was exhibited by the studies scrutinized, indicating that learners who participated in practical science work performed better in terms of comprehension and retention of scientific concepts than those who underwent traditional instruction, where they received information through lectures alone. However, the efficiency of science practical work does not remain the same and changes due to various factors, such as the competency of teachers, the availability of well-equipped laboratories, and structured educational approaches. Hands-on science teaching also implies a supportive, active learning approach, inquiry-based learning, and an orientation toward practical application, which subsequently develops critical-thinking skills and problem-solving abilities.

The best way to make practical work more effective is to schedule lessons that align with teaching objectives and create hands-on experiences that are both significant and accessible to all learners. Probands-notice also involves considering students' reading capabilities and learning styles, as well as ensuring that they are given adequate time to learn. Science teachers are expected to create learning environments that foster scientific inquiry and introduce real-life issues, particularly those with which students are familiar in their local environment. Locally based learning materials can bring scientific topics closer to real-life experiences, contributing to building a more profound understanding.

To achieve sustainability in the success of practical science work, further studies are needed on the effects of teacher training, curriculum development, and school infrastructural provisions on the enforcement of practical work in various learning institutions. Teachers are advised to familiarize themselves with classroom dynamics and practical teaching methods to accommodate the diverse needs of students when engaging in practical science activities. Through sensitive incorporation, practical science work may form part of a core framework in contemporary science education, teaching students the necessary skills for academic performance and the ability to think critically in addressing challenging global and local issues.

However, these contributions must be interpreted in light of the possible biases identified in this review. The dominance of studies carried out in developing countries reinforces the relevance of the results for low-income contexts but may restrict their relevance for high-income educational systems with different infrastructures and pedagogical cultures. Similarly, the dependence on open-access studies for transparency purposes, which is a laudable requirement of open science, may underestimate evidence published in subscription journals. Taken together, these findings indicate that while the study provides good guidance for educators, curriculum developers, and policymakers, especially in a resource-constrained setting, the findings cannot be generalised universally.

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