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Practical work in science education: a systematic literature review

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Practical work has taken a leading role in science teaching, particularly since the 1960s. Its goals are mainly oriented toward the development of sensitivity and taste for the study of physical and natural phenomena, bringing students closer to the daily reality experienced by researchers working in these areas of knowledge, while promoting educational success. However, these purposes have not always been achieved so, over time, limitations to the way that practical work has been developed have also been identified. In order to recognize the current state of the art on the development of the practical work in the teaching of sciences, a systematic literature review was designed, especially focused on the definition of the concept of practical work, its advantages, evaluation methodologies, and the criticism/limitations attributed to its implementation. To this end, four databases and one aggregator were used, to identify 53 international scientific publications. Analysis of this *corpus* allowed the identification of 8 categories associated to the concept of practical work, 5 categories associated to its advantages, 6 categories with the types/methodologies of evaluation and 5 categories associated with the limitations of this methodology. (From this analysis) it is concluded that most authors considers that the main idea integrative idea of the concept of practical work should be the manipulation of materials in practical activities (hands-on style), and the main advantage of this methodology comes from the fusion between the development of practical skills and the conceptual understanding (minds-on). In the evaluation methods, the context, procedures and specific instruments are favored and the main limitation pointed to this methodology is that the way practical work is implemented, is often not in agreement with the methods and techniques used by scientists and researchers.

KEYWORDS

science education, practical work concept, practical work advantages, practical work assessment, practical work disadvantages, systematic review

1. Introduction

The role of practical work in science teaching has long been a theme of intense debate and reflection, a function of scientific experimentation being understood as a landmark of modern science, particularly, from the days of Bacon (Rheinberger, 2001). The reflection on the teaching of science, more specifically, over the development of the practical work, took on special importance, in the early 1960s, in the United States of America, during the Cold War, from the moment the Union of Soviet Socialist Republic launched the first satellite to orbit the Earth. Mayer (1964) wrote that "the impact of this grape-fruit sized object on the American ego was several orders of magnitude greater than any event of this century" (p. 226). The missing step was taken and triggered a profound revolution, both in the curricula as well as in the methodologies applied in the teaching of sciences, with echoes that quickly made themselves felt a bit all over the globe. Programs such as the *Biological Sciences Curriculum Study (BSCS)* and the *Earth Science Curriculum Project (ESCP)* establish that in addition to their content, the Biological Sciences and Geosciences programs, respectively, should reflect, from that moment on, the science enterprise in its broadest scope, adopting a more investigative spirit, contrary to its teaching as mere observational sciences.

To reach this goal, practical, investigative, laboratory and field activities in the programs of these areas of knowledge would have to be included. Simultaneously, the need to create new materials that allow the proper development of new strategies and approaches of teaching should also be included, giving a big emphasis to the use of multimedia resources. Within the scope of the BSCS it was produced, for example, a sequence of forty movies allusive to specific research topics, developed in a way to promote the student's engagement, as well as debate in a classroom environment. These movies served as a source of research data regarding biologic problems, allowing the observation, formulation of hypothesis, gathering and analysis of data as well as the establishment of temporary conclusions reached by the students.

Both programs and materials were planned, written, and produced by multidisciplinary teams, where the ESCP, for example, counted with the contribution of scientists specialized in the most diverse fields of science, such as Astronomy, Physical Geography, Geophysics, Geology, Geochemistry and Oceanography. These scientists developed a very important collaborative work, integrating secondary school science teachers, as well as science educators, in their work teams (Heller, 1964).

At the end of the 20th century, practical work continued to enjoy a privileged status in the science teaching, however, Hodson (1996) argues that, paradoxically, practical work is simultaneously overused and underused. Overused, in the sense that the teachers develop it with the expectation of reaching all the science learning objectives. And underused, where its real potential is rarely fully explored. In a way to get out of this confusing and educationally unproductive situation, the author proposes a reconceptualization of practical work in terms of three associated purposes which would contribute to helping students: (a) learn science; (b) learn about science, developing an understanding about the nature and scientific methods, as well as the awareness regarding the complex interactions between science, technology, society and the environment; and (c) make them capable of doing science – including them and developing their experience in scientific research and problem solving Hodson (1996).

Reflecting on the arguments that justify carrying out practical work, Wellington (1998) suggests that it can be grouped into three main domains: the cognitive, the affective, and the skills and processes. In the arguments regarding the cognitive domain, the author suggests that practical work allows to illustrate, verify and affirm theoretical content. Thus, it helps the students to improve their understanding of science, allowing them to "visualize" scientific laws and theories, which promotes their conceptual development. Regarding the affective arguments, the author demonstrates that because practical work is motivating and exciting, it will contribute to an increased interest in science, consequently helping the students to better remember lessons, developing their memorization abilities. Lastly, about the domain of skills and processes, Wellington (1998) indicates that practical work has the potential to develop transferable skills of great relevance, not only for future scientists, but it is also of great use to students with other callings. Some examples of these skills are the observation, the measurement, the prediction, and inference.

However, the author shows in their study that for each set of arguments used in favor of practical work, there are also counterarguments. For example, concerning the cognitive domain, Wellington (1998) concludes that in certain situations practical work might confuse just as easily as it may help with the conceptual understanding. As for the affective domain, they conclude that some students may even "turn off" their concentration, especially when the practical work goes wrong, or when they fail to understand its purpose. Lastly, regarding the skills and processes domain, the author recognizes there is little proof that the skills learned in science are in fact general and transferable, or that they still present vocational value. Nevertheless, even though practical work is seen as a fundamental part of the science teaching, its relevance has never stopped being criticized. Wellington (1998) warned that beyond its ability to excite, improve the illustration and understanding of phenomena, practical work can also be criticized due to economic matters, the ability to cause conceptual confusion, issues of bias of gender and, also, and the possibility of arousing less ethical behaviors from teachers and students in the classroom.

Science research refers to how scientists study, disclose ideas, explain and justify propositions regarding the natural world, based on the evidence that resulted from scientific work (Hofstein and Lunetta, 2003; Millar and Abrahams, 2009; Osborne, 2014; Koliander, 2019) and, equally, in more authentic ways through which students can investigate the natural world, propose ideas, explain and justify evidence based claims, acquiring and developing the scientific approach (Itzek-Greulich and Vollmer, 2017; Shana and Abulibdeh, 2020; Aydin et al., 2022).

To reflect on the efficiency of a teaching and learning activity of any nature, it is useful to consider the different steps in the development of such activity, and the monitoring of what happens when it is promoted. For that reason, in the assessment process of the efficiency of a certain practical work, four structural dimensions should be integrated: (a) the developers' objectives (what is expected for students to learn); (b) the tasks guidelines (what is expected for students to do); (c) what happens in the classroom (what students actually do); and (d) learning outcomes (what students actually learn).

Wei and Li (2017) studied the teachers' perceptions of scientific experimentation and the implications for the restructuring of practical work in science teaching, developed by scientists and students in schools. The results from their research suggest that participants' views on experimentation are generally framed in eight dimensions (conceptual, epistemological, procedural, material, social, safety, temporal and pedagogical) although they show uneven distributions among them. Thus, for example, regarding the experiments carried out by students, the three main dimensions are the pedagogical, the experimental and the epistemological; for the scientific experiments are the procedural, epistemological and the material.

This and other important reasons, such as the fact that the conceptual and social dimensions, widely discussed in literature and rarely mentioned by the study participants, have made different authors of studies present in the *corpus* of this systematic review defend a greater approximation of practical work developed in science teacher education programs for practical work effectively developed by scientists while conducting experiments (Toplis, 2012; Abrahams et al., 2013; Donnelly et al., 2013; Anza et al., 2016; Musasia et al., 2016; Wei and Li, 2017; Oguoma et al., 2019; Adamu and Achufusi-Aka, 2020; Babalola et al., 2020; Wei et al., 2020; Pols et al., 2021). Because of this, they suggest that courses, modules, and teacher training programs should focus on how real scientific experiments are developed, what scientists actually do when conducting these experiments, and how the scientific experiments are performed in different social contexts. It is, therefore, essential that science teachers can be provided with opportunities to learn how to transform traditional practical work in scientifically grounded experiments at a conceptual, epistemological, and procedural level. In summary, it is possible to contest that the quality of the practical work developed in the scope of science teaching depends, not only on the frequency that it is used, but also, and mainly, on the quality with which it is accomplished.

Based on this framework, this article presents the results of a systematic review of the literature on the state of the art in the development of practical work in science teaching. This type of literature review becomes advantageous in the way that it suggests the adoption of explicit and systematic procedures in its performance, making the emergence of biases introduced by their authors, less likely.

With this, it is possible to understand that if the process of including studies in the literature review is not explicit, it is not possible to determine the suitability of that selection, nor whether the process was performed in a rigorous, consistent, and reasoned way. Thus, it would become more difficult to correctly interpret the meanings of the outcomes of the literature review (Bryman, 2012; Gough et al., 2012; Page et al., 2021).

This systematic review starts from the following research question: what is the current state of the art on practical work in science teaching at the pre-university education level? In order to arrive at a more conclusive answer, this guiding question is divided into the following sub-questions: (a) what aspects are integrated in the concept of practical work; (b) what are the defined advantages attributed to the development of the practical work in science teaching?; (c) what assessment types/strategies are performed for the development of practical work?; (d) what are the defined disadvantages attributed to the development of the practical work in science teaching? It is intended that this review essentially reflects the students, teachers, and researchers on this matter.

2. Methods

2.1. Data sources, search engines and key words

The data collection process for this systematic literature review, was performed in four international data bases (ERIC; Google Scholar; Scopus and Web of Science) and in Portuguese database aggregator (B-on). The research in these data sources respected the assumptions established in a research protocol, which included inclusion and exclusion criteria, with the aim to identify the documents that are more relevant for the development of this review. It is also included in the protocol the goals associated to this systematic literature review, the main research question, as well as essential keywords to be applied during research.

The first step was to formulate the big guiding question for the entire investigation, using the research strategy tool SPIDER (Sample, Phenomenon of Interest; Design, Evaluation, Research type), for this purpose, as it is considered the better adapted for investigations of qualitative natures rather than the PICO strategy (Population, Intervention, Comparison, Outcome) (Cooke et al., 2012).

The considered sample were pre-university education institutions. The *Phenomen of Interest* identified was the employment of practical work in the teaching of science. The Design included a qualitative approach embodied in the performance of a systematic review of the literature. The Evaluation consisted of determining the status of the art over the implementation of practical work in science teaching and, lastly, it was determined that the Research Type would include studies carried out with the quantitative, qualitative methodology and the mixed methodology.

Going off the research question, for the research in the different databases and selected aggregator, the following keywords were defined: practical work, science education, secondary schools. The research protocol was registered in the International Platform of Registered Systematic Review and Meta-analysis Protocols – INPLASY, and its structure is outlined in Table 1 (Oliveira and Bonito, 2023).

2.2. Study selection: inclusion and exclusion criteria

The study selection in the *corpus* under analysis involved the definition of inclusion criteria and exclusion criteria. The establishment of these criteria worked as a filter that allowed refining the research, in order to identify the most relevant publications and

TABLE 1 Structure of the investigation protocol.

Goals of systematic literature review	Create an overview of how practical work is currently conceived and applied for teaching sciences on the secondary education level, according to students, teachers and researchers.
Research question	What is the state of the art of practical work in science teaching in a pre-university education level?
Keywords	Practical work; Science education; Secondary schools
Inclusion criteria	Complete Open Access documents; Peer reviewed studies; Studies developed on/how sciences are taught on pre-university education institutions; Documents written in English.
Exclusion criteria	Systematic Literature Reviews; Bachelor thesis dissertations/Final papers; Master's thesis dissertations; Documents published prior to 2011

TABLE 2 Findings from initial identification of studies to be included in investigation corpus.

Databases	Query options	Query criteria	Document count
B-on	*Limitators* - Latest 10 years - Peer reviewed - Available from library - Full text available *Expanders* - *Search whole article body* - *Search for equivalent topics*	"Practical work in science education" AND "secondary schools"	30
ERIC	- Latest 10 years - Peer reviewed	"Practical work" AND "science education" AND "secondary schools"	58
Google scholar	- Latest 10 years	Allintitle: "practical work" "science education" OR "secondary schools"	43
Scopus	- Latest 10 years	"Practical work" AND "science education" AND "secondary schools"	19
Web of science	- Latest 10 years	"Practical work" AND "science education" AND "secondary schools"	13
Total			163

better framed with the main research question. This way, the inclusion criteria to build the *corpus*, considering complete documents available in open access, peer-reviewed studies, studies developed in/about science teaching in pre-university teaching establishments and publications written in the English language. Also, with of refining the research, the exclusion criteria were defined with the goal to remove from the data collection publications resulting from systematic literature reviews, final degree work, masters dissertation and publications prior to 2011 (Table 1).

The fact that we chose to exclude studies published before 2011 does not mean that we disregard the structuring and extremely important research work carried out by many leading authors until then. On the contrary, it was a strategic choice, given the need to set a time frame for this systematic literature review, considering that one of its objectives is to help understand, in the most possible current way, the state-of-the-art on practical work in science teaching. Therefore, for this contemporary portrait of its conceptual dimension, the assessment methodologies used, and the advantages and disadvantages perceived by researchers and educators, we decided to focus this systematic literature review on research on practical work in science education, which took place after 2011. Also, the authors of this systematic literature review consider that doctoral theses correspond to the characterization of in-depth research projects, developed over a period of time, which allow obtaining solid results with a high degree of reliability and validity. Therefore, these manuscripts were considered in the process of selection and constitution of the *corpus* under study.

Another important inclusion criteria of this systematic literature review is the inclusion of research on pre-university education, particularly at the secondary education level. According to the International Standard Classification of Education (ISCED), this level is divided between lower secondary education (level 2) and upper secondary education (level 3), in a pathway that in different countries starts between 10–13 years and ends between 17–18 years of age (UNESCO, 2012).

Although research studies were not excluded on the basis of their country or language of origin, this systematic literature review established, as one of its inclusion criteria, the inclusion of studies published in English. This strategic option is not intended to take away the merit of important research studies developed and published in other languages, namely those from the Ibero-American space. It was a decision taken with the aim of considering manuscripts that are more likely to be interpreted by a wider audience of readers, increasing, consequently, the probability of having a greater impact on the conceptions and practices of a larger number of educational communities.

2.3. Synthesis of results and quality assessment

The research done in the four databases and the in the selected database cluster was performed on July 20, 2021. After applying the defined keywords, using adequate descriptors, employing specific Boolean operators, and fulfilling the criteria established in the planned research protocol, the initial result of data collection found 163 publications of potential interest (Table 2).

In the next stage, duplicate publications were removed ($n = 14$) before moving onto the screening phase, resulting in 149 publications. In the initial phase of the screening process, some publications were excluded through an analysis over the title's adequacy ($n = 20$), leaving the remaining ones identified for recovery ($n = 129$). From these last records, a small number was not retrieved, after an analysis over the adequacy of the abstract ($n = 10$). Thus, 119 publications were evaluated for eligibility, some of which are inaccessible ($n = 13$), others were final degree papers or masters dissertation ($n = 3$) and others corresponded to publications outside the scope of investigation ($n = 50$), that is, they did not address, in a clear and unequivocal way, one or more of the following dimensions related to practical work: concept, advantages, methodologies/typologies of assessment; limitations. At the end of the screening process, 53 studies were selected to constitute the *corpus* of this systematic literature review. The process to identify the studies considered is found on a flow diagram (Page et al., 2021) (Figure 1).

After obtaining the definitive number of studies to be considered, the *corpus* was constituted (Table 3). The analysis, characterization and organization of the studies was performed with the support of the Mendeley bibliographic management software (. Pdf visualization and analysis functionality), and research was carried out on the following dimensions of practical works: concept, advantages; methodologies / typologies of assessment; limitations. The results were recorded in a .docx file for later analysis.

Lastly, the data were synthesized, and the quality of the evidence was evaluated, by triangulating the information obtained through each individual study, integrating it into a holistic view of the state of the art on practical work in the last 10 years, with the goal to disperse the results obtained through its publication.

3. Results and discussion

The analysis of the distribution of articles that constitute the *corpus* reveals that most studies show a qualitative research approach ($n = 31$; 58.5%), followed by studies of a quantitative nature ($n = 18$; 34.0%) and those that adopted a mixed research approach, merging both data collection and qualitative data analysis methods, with quantitative methods ($n = 4$; 7.5%) (Table 4). The studies included in the classification categories defined for each

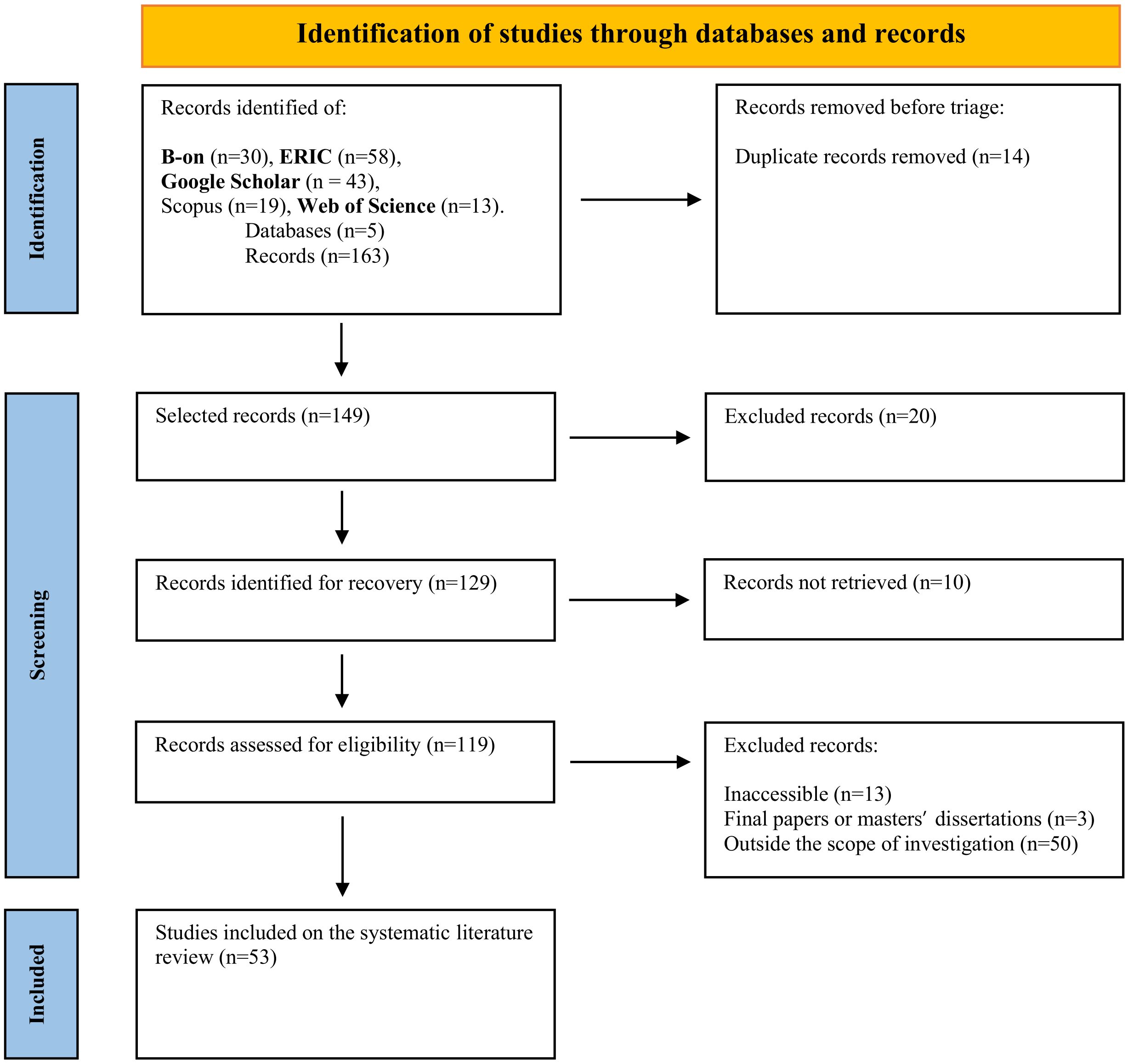

FIGURE 1
Screening results for the constitution of the corpus.

TABLE 3 Studies included in the constitution of the corpus.

Characteristics	S1	S2	S3	S4	S5	S6		
Authors	Babalola et al. (2020)	Donnelly et al. (2013)	Ferreira and Morais (2014)	Oguoma et al. (2019)	Rukavina et al. (2012)	Shana and Abulibdeh (2020)		
Country	Ghana; South Africa; Nigeria; Tanzania	Ireland	Portugal	South Africa	Croatia	United Arab Emirates		
Type of study	Mixed methods research	Multiple case study	Mixed methods research	Quantitative research approach (survey)	Quantitative research (survey)	*Quasi*-experimental research		
Objectives	Examination of the current views on the aims of practical physics teaching in sub-Saharan Africa.	Determination of how a virtual chemistry laboratory may support greater teacher enactment of inquiry-based approaches to practical work.	Analysis of the level of complexity of practical work in science curricula, focused on the discipline of Biology and Geology at high school.	Investigation of the teacher's concerns with the implementation of practical work in Physical Sciences by the Curriculum and Assessment Policy Statement (CAPS)	Determination of the interest and motivation among children aged 10 to 14 years, who participated in science or mathematics workshops.	Evaluation of the overall effect of practical work on students' academic attainment in science, specifically Chemistry and Biology.		
Instruments	Semi-structured interview protocols; Surveys; Audio recordings; NVivo Pro 11 Software.	Inquiry Science Implementation Scale (ISIS); video record; Reformed Teaching Observation Protocol (RTOP); Final interview	Instrument to characterize: the complexity of scientific knowledge; the cognitive skills; the relation between theory and practice, the explicitness of practical work and the analysis made of each unit of analysis.	Questionnaires; Statistics Analysis Software.	Survey; Statistical Software Package STATISTICA	Pre-test and pos-test to assess the effect of practical work on high school students' understanding of science.		
Subjects	Students (*N* = 80) Teachers (*N* = 55) Other educational staff (N = 30)	Teachers (*N* = 4; three males and one female)	Students (*N* = 96) Teachers (*N* = 4)	Teachers (*N* = 81)	Students (*N* = 1,240; Age 10–14)	Students (*N* = 98)		
Characteristics	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**
Authors	Sund (2016)	Toplis (2012)	Abrahams et al. (2014)	Abrahams et al. (2013)	Akuma and Callaghan (2019)	Musasia et al. (2016)	Andersson and Enghag (2017)	Bohloko et al. (2019)
Country	Sweden	England	England	England	South Africa	Kenya	Sweden	Lesotho
Type of study	Empirical case study research	Grounded theory research	Multi-site case study	Documentary analysis	Multimethod case study approach	Quasi-experimental research	Case study research	Quasi-experimental research

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6		
Objectives	Investigation of the obstacles that prevent teachers to make individual assessment of student's practical abilities in science.	Investigation of students' views about the role that practical work plays in their school science lessons.	To evaluate the impact of the Getting Practical: Improving Practical Work in Science CPD program on teachers' ideas and practice in science practical work in primary and secondary schools in England.	Review how practical work, including practical skills, is currently summatively assessed in school science in a number of countries and compare with how other subjects, such as music and modern foreign languages, summatively assess skills.	To determine in what extent is inquiry-based practical work being implemented in selected resource-constrained South African physical sciences classrooms.	The study sought to find out the difference in academic achievement in physics between students taught using intensive practical activities and those taught using conventional teaching methods, mostly theoretically.	To investigate the relation between the interaction and content of students' communication and outcomes of their actions, with the purpose of finding new knowledge for informing teachers in their choice of instruction during practical work.	To investigate the effectiveness of introducing open-source YouTube videos in the teaching and learning of the Chemistry topic 'Group Properties' at a high school in Lesotho.
Instruments	Mounted video cameras; Spy camera glasses.	Notes of the observed lessons; Semi-structured interview protocols.	Interview scripts; Observational field notes; pre- and post-CPD training observations in practical lessons.	Documentary analysis.	Semi-structured interview protocols, Classroom observation protocol; Learner worksheets.	End of Term One Form Two examination (EOTOFTE); Performance Tests on the Chosen Topics (PTCT).	Video recordings; Transcripts;	JC Science Score; Pre-test; Post-test
Subjects	Teachers ($N = 2$) Students ($N = 38$; ages: 15–16)	Students ($N = 29$)	Teachers ($N = 30$)	Examination of the science curriculum for 5–16 and 16–18 years-old	Teachers ($N = 6$) Demonstrator ($N = 1$)	Students ($N = 450$)	Students ($N = 20$) Teacher ($N = 1$)	Students ($N = 109$)
Characteristics	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**
Authors	Erduran et al. (2020)	Fadzil and Saat (2019)	Haigh et al. (2012)	Hamza and Wickman (2013)	Harrison (2016)	Itzek-Greulich and Vollmer (2017)	Köksal (2018)	Kácovský and Snětinová (2021)
Country	Norway	Malaysia	New Zeland	Sweden	England	Germany	Turkey	Czech Republic
Type of study	Documentary analysis	Qualitative research	Qualitative research	Practical epistemology analysis	Qualitative research	Quantitative research	Survey	Quantitative research

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6		
Objectives	To investigate how practical work is represented in the assessment frameworks of several countries that demonstrate above average performance in the latest PISA science assessments.	To discuss the development of a resource guide in assessing secondary school students'' manipulative skills during practical work.	To determine how does engagement in illustrative practical work enhance students' understandings of the redox reaction occurring when steel wool is added to copper sulfate solution.	To compare how pairs of high-school students engage with the educational artefacts and scientific ideas on offer in the classroom in two different school science activities traditionally considered to lie far apart on the theory–practice scale.	To determine if the use of targeted discussion improves learning through practical work.	To research on activity emotions (state) and motivational outcomes (situational interest and situational competence) in science education.	To construct a self-efficacy scale for pre-service science teachers on using fieldtrips. The study also aimed to determine whether these beliefs vary by gender, class, secondary school type, whether fieldtrip was used in high school and university courses.	To identify factors predetermining students' positive acceptance of physics demonstrations.
Instruments	Science summative assessments; PISA 2015 scores.	Diagnostic tests; Assessment rubrics for activity A and B; Description of the competency level of manipulative skills.	Pre- and post-practical tests; Surveys; Interview.	Audio-recordings; Video-recordings;	Questionnaires; booklets; Audio-recording.	Learning-related emotion scale; Situational interest scale; science grades from the last school certificate; multiple-choice test; intrinsic motivation scale; Consciousness scale; Cognitive ability scale.	Self-Efficacy Beliefs on Fieldtrip Scale;	The modified Intrinsic Motivation Inventory questionnaire.
Subjects	Students' PISA science assessments from Singapure, USA, Canada, New Zeland and England.	Teachers ($N = 40$)	Students ($N = 17$)	Students ($N = 10$; ages: 16–17)	Students ($N = 700$; ages: 11–18)	Students ($N = 1{,}228$; age on average: 15,3)	Pre-service science teachers ($N = 249$)	Students ($N = 4{,}962$; ages: 15–20)
Characteristics	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
Authors	Karpin et al. (2014)	Kennedy (2013)	Abrahams and Reiss (2012)	Oyoo (2012)	Phaeton and Stears (2017)	Pols et al. (2021)	Ramnarain and de Beer (2013)	Sharpe and Abrahams (2020)
Country	Finland	Ireland	England	Kenya	South Africa	Netherlands	South Africa	England
Type of study	Quasi-experimental	Documentary analysis	Multi-site case study	Qualitative research	Case study	Qualitative participatory research design	Case study	Mixed methods research

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6		
Objectives	To analyze to what extent in designed lessons students learned to apply structural models in explaining the properties and behaviors of various materials.	To describe recent developments in Ireland to promote a greater interest in science among students in the 12–15 age group by means of practical work involving Inquiry Based Science Education (IBSE).	To report the first of two evaluations of a national project designed to improve the effectiveness of practical work in both primary and secondary schools.	To report and discuss findings in an investigation of physics teachers' approaches to use of and their beliefs about classroom instructional language.	To analyze the alignment between the intended and implemented A-Level Biology curriculum through the lens of teachers' interpretation of the Zimbabwean curriculum.	To investigate whether students who have just finished the compulsory part of science education in the Netherlands have the ability to analyse and interpret exper- imental data by constructing adequate data representations and drawing qualified, appropriate, defensible conclusions from these data.	To report the experiences of three 9th-grade South African students in doing open science investigation projects for a science expo.	To examine students' attitudes to practical work in biology chemistry and physics in secondary schools in England.
Instruments	Pre- and post-tests.	Documentary analysis	Audio recordings; Interviews; Observational field notes.	Direct classrooms observations; Interview scripts; Audio-recordings; Written test; outline of a student focus group interview schedule; a student in- depth interview schedule; classroom observation framework/ schedule; an outline of teacher interview schedule.	Padilla's (1990) categories of Science Process Skills; Questionnaire; Interview scripts.	Interview scripts.	Interview scripts; Qualitative data software.	Questionnaires; Audio-recordings; Field notes.
Subjects	Students ($N=45$; age: 16)	Examination of the subject Science which is studied as part of the Junior Certificate examination for 15-year-old students	Students ($N=857$)	Teachers ($N=9$)	Teachers ($N=5$)	Students ($N=51$; age on average: 15)	Students ($N=3$; ages: 13–14)	Students ($N=607$; ages: 11–15)
Characteristics	**S31**	**S32**	**S33**	**S34**	**S35**	**S36**	**S37**	**S38**
Authors	Wei et al. (2020)	Wei et al. (2019)	Wei and Li (2017)	Wei and Liu (2018)	Xu and Clarke (2012)	Adamu and Achufusi-Aka (2020)	Preethlall (2015)	Anza et al. (2016)
Country	China	China	China	China	Australia	Nigeria	South Africa	Ethiopia

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6		
Type of study	Multiple case study	Survey	Grounded theory research	Case study	Qualitative research	Descriptive survey design.	Multiple case study	Descriptive survey design
Objectives	To investigate how three beginning science teachers deal with practical work during their first 2 years of teaching careers in high school.	To investigate the contributions of different sources in developing science teachers' practical knowledge of teaching with practical work.	To explore science teachers' perceptions of experimentation for the purpose of restructuring school practical work in view of science practice.	To examine an experienced chemistry teacher's pedagogical content knowledge (PCK) of teaching with practical work in China.	To report a detailed analysis of two lessons on density in a 7th Grade Australian science classroom, employing the theory of Distributed Cognition	To investigate the extent of integration of practical work in the teaching of chemistry by secondary school teachers in Taraba State, Nigeria.	To establish the relationship of teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW) in the Life Sciences.	To explore factors that influence practical work in chemistry for secondary schools in Wolaita Zone, Ethiopia.
Instruments	Interview protocol; Field notes; Lesson plans.	Questionnaire;	Interview scripts.	Interviews; Classroom observation notes; Textbooks; Lesson plans.	Video recordings; Interview scripts; Copies of lesson materials; Student written work; The results of the International Benchmark Test for Science; Student class tests; Teacher questionnaires.	Questionnaires.	Questionnaire; Interview scripts; Lesson observation notes; Documents with tasks completed by the participating teachers; Teacher and learner artefacts; South African Biology and Life Sciences curricula.	Questionnaires; Interview scripts.
Subjects	Teachers ($N = 3$)	Teachers ($N = 280$)	Teachers ($N = 87$)	Teacher ($N = 1$)	Students ($N = 27$) Teacher ($N = 1$)	Students ($N = 45$)	Teacher ($N = 4$)	Students ($N = 75$) Teachers ($N = 56$) Principals ($N = 5$)
Characteristics	**S39**	**S40**	**S41**	**S42**	**S43**	**S44**	**S45**	**S46**
Authors	Childs and Baird (2020)	Danmole (2012)	di Fuccia et al. (2012)	Malathi and Rohini (2017)	Wilson (2018)	Musasia et al. (2012)	Ruparanganda et al. (2013)	Sani (2014)
Country	England and Wales	Nigeria	Germany	India	England	Kenya	Zimbabwe	Malaysia
Type of study	Narrative critical evaluation	Descriptive survey design	Documentary analysis	Descriptive survey design	Design-based research approach	Quasi-experimental research	Qualitative research	Case study

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6		
Objectives	To analyze the policy trajectory for the assessment of science practical work, through the GCSE, in the English National Curriculum from 1988 to the present.	To investigate biology teacher views on practical work on the Nigerian senior secondary schools.	To give account of the development of practical science work in German schools and to discuss the most prominent trends in practical science efforts in German secondary science education which have taken place in recent years.	To identify the problems that are experienced by physical science teachers in doing practical work.	To conceive, develop, and pilot Labdog: a novel web-based technology for the teaching laboratory.	To investigate the effect of practical work on girls' performance in physics; To determine whether there is an attitude change toward physics for girls as a result of participating in practical work; To investigate whether practical work enables the girls to acquire science process and practical skills; To determine the effect of practical work on girls enrollment in the physics class in form three.	To explore possibilities of implementing the Project Approach as an alternative to Regular Laboratory Practical Work in Ordinary Level Biology Teaching in Rural Secondary schools where science equipment is limited or where there are no laboratories.	To gain an understanding of teachers' views and practices in conducting practical work in lower secondary schools in Malaysia.
Instruments	Published research work; Policy documents.	Questionnaire.	Published research work.	Questionnaire.	Meaningful learning in the laboratory instrument (MLLI); Corpus of responses to in-lab Labdog questions; Open-answers given by laboratory members	Pre-tests (end of form one term three physics examinations); Post-tests (Student's Achievement Tests; Form Two Students Attitude Questionnaire); Observation Checklist for Skills Acquired.	Questionnaire; Lesson observation notes; Focus group discussion notes.	Interview scripts; Classroom observation field notes; Documental analysis notes.
Subjects	Examination of the GCSE coursework (student ages between 11 and 16 years old).	Teachers ($N = 96$)	Examination of the trends in Practical Work in German Science Education.	Teachers ($N = 30$)	Students ($N = 46$; ages: 18–40)	Students ($N = 271$)	Teachers ($N = 12$) Lecturers ($N = 3$)	Teachers ($N = 3$) Students ($N = 35$)

(Continued)

TABLE 3 (Continued)

Characteristics	S1	S2	S3	S4	S5	S6	
Characteristics	**S47**	**S48**	**S49**	**S50**	**S51**	**S52**	**S53**
Authors	Tesfamariam et al. (2014)	Viswarajan (2017)	Lowe et al. (2013)	Mamlok-Naaman and Barnea (2012)	Mkimbili and Ødegaard (2019)	Šorgo and Špernjak (2012)	Ye et al. (2021)
Country	Ethiopia	England	Australia	Israel	Tanzania	Slovenia	China
Type of study	Quasi-experimental research	Documentary analysis	Survey	Documentary analysis	Group-interview study	Documentary analysis	Fuzzi delphi technique and Analytic hierarchy process
Objectives	to explore the possibility of using the SSC approach as a means of performing chemistry hands-on practical activities in Ethiopian secondary schools, and thereby reducing the need for costly equipment and expensive laboratories	To explore the range of literature available on the effectiveness of science practical work in English secondary schools and consider the possible effects of the removal of internal assessment of practical work from the GCSE curriculum.	To describe trials of the use of remote laboratories within secondary school science education, reporting on the student and teacher reactions to their interactions with the laboratories.	To describe the chemistry laboratory curriculum in Israel, its development, implementation and assessment strategies.	To invite a selection of Tanzanian students to reflect on what motivates them in learning science and their suggestion with regards to improving students' motivation.	To analyse and compare syllabi of Biology, Chemistry and Physics to find out if they are enhancers or blockers for the introduction of active, student-centered teaching methods, particularly hands-on laboratory work, in everyday teaching practice at lower and general upper secondary schools in Slovenia.	Research on the core competences of middle school science teachers.
Instruments	Chemistry concept test; Student questionnaire; Individual teacher interview; Classroom observation notes.	Published research work.	Student's survey; Teacher's survey.	Published research work.	Interview guide; Audio recordings.	Syllabi booklets.	Fuzzy Delphi questionnaire; Analytic Hierarchy Process questionnaire.
Subjects	Students ($N = 383$; ages: average 17) Teachers ($N = 6$)	–	Students ($N = 112$; ages: 9–11) Teachers ($N = 13$)	–	Students ($N = 46$; ages: 15–19)	–	Science teachers ($N = 10$) Science education administrators ($N = 8$) University professors ($N = 12$)

(Continued)

TABLE 4 Corpus organization by research methodology.

Research approach	*f* (%)	Research design	*f* (%)	Studies
Qualitative research	31 (58.5)	(Multiple) Case study research	17 (32.1)	S2, S7, S9, S11, S13, S17, S19, S25-S27, S29, S31, S34, S35, S37, S45, S46
		Documentary analysis	7 (13.2)	S10, S15, S24, S41, S48, S50, S52
		Grounded theory approach	3 (3.8)	S8, S33
		Group-interview study	1 (1.9)	S51
		Design Research	1 (1.9)	S16
		Practical epistemology analysis	1 (1.9)	S18
		Qualitative participatory research design	1 (1.9)	S28
		Narrative critical evaluation	1 (1.9)	S39
Quantitative research	18 (34.0)	Survey	10 (18.9)	S4, S5, S21, S22, S32, S36, S38, S40, S42, S49
		Quasi-experimental research	6 (11.3)	S6, S12, S14, S23, S44, S47
		Cluster Randomized Trial	1 (1.9)	S20
		Fuzzi delphi technique and Analytic hierarchy process	1 (1.9)	S53
Mixed methods research	4 (7.5)	Exploratory sequential mixed methods	1 (1.9)	S1
		Convergent mixed methods	1 (1.9)	S3
		Explanatory sequential mixed methods	1 (1.9)	S30
		Design-based research approach	1 (1.9)	S43

dimension under analysis (conceptual dimension, advantages dimension, evaluation dimension and disadvantages dimension) are not exclusive. This means that each study of the *corpus* under analysis, may include indicators from more than one category and be framed in different dimensions. Thus, there will be situations in which we may have identified the same study in different dimensions and in different categories. The global overview of the considered dimensions and their associated categories is presented in an organizational chart (Figure 2).

3.1. The concept of practical work

There is not a very broad consensus on the definition of practical work. It is possible to find references to several authors who, in turn, present different conceptions regarding the characterization of the concept of practical work. On the other hand, some similarities are also seen, in this conceptual issue, between the international studies considered here. The content analysis of the different investigations for the *corpus,* allowed the establishment of a distribution of studies by eight structuring categories, as indicated in Table 5.

Some studies integrate the concept of "hands-on skills" into that of practical work (S3, S4, S7-S11, S15, S16, S18, S20, S21, S23-S25, S27-S30, S32-S34, S36-S38, S40- S50, S52). Thus, in 69.8% ($f = 37$) of the studies, a conception of practical work that represents a direct interaction with equipment or materials, individually or in small groups, contemplating observation and/or manipulation, particularly associated with practical activities, is presumed. Others, however, associate practical work to the mobilization of practical skills in handling materials applied to scientific investigative processes (S8-S11, S15, S16, S18, S20, S21, S23-S25, S27- S30, S32-S34, S36-S38, S40-S45, S48-S50, S52). In this category are found 60.4% ($f = 32$) of the studies under review.

The factor that assumes prominent relevance in the definition of the concept, for another study group (37.8%, $f = 20$), is the fact that practical work presumes the mobilization of scientific knowledge, in order to allow the understanding of the processes of certain phenomena, in line with a "minds-on" approach, promoter of critical thinking (S3, S15, S16, S19, S20, S23, S26, S28, S29, S35-S37, S41-S45, S48, S50, S52). Another relevant idea is that practical work should also assume a strong involvement in the process of developing investigative queries and designing experimental procedures, in a logic of promoting of Inquiry-Based Learning (S4, S11, S21, S24, S27, S29, S34, S37, S38, S43, S51, S52), with this aspect highlighted in 22.6% ($f = 12$) of the studies.

Learning through everyday phenomena that promote student motivation and engagement as a result of more relevant learning episodes, drawn from experiences and selected contexts, allows building a fifth category (7.5%, $f = 4$) with this integrating element (S12, S29, S33, S35).

In a sixth category (5.7%, $f = 3$), the studies considered are the ones that show the integration of aspects associated with "scientific communication," in the conceptual definition of practical work (S4, S24, S27). One study (1.9%, $f = 1$) integrates the possibility that this methodology can be an accessible and low-cost alternative for science learning, in the conceptual framework of practical work (S19), and

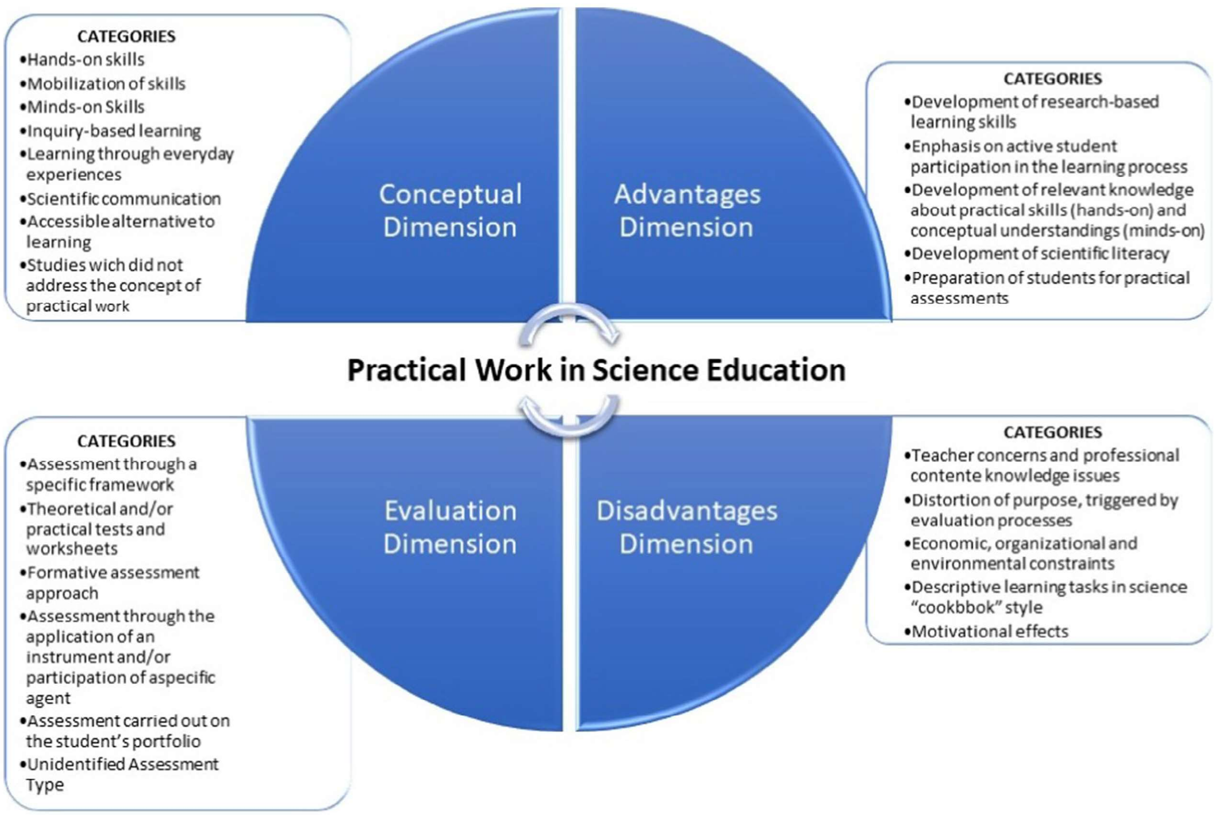

FIGURE 2
Categories of the practical work dimensions under analysis.

TABLE 5 Elements integrated within the concept of practical work.

Categories	*f* (%)	Studies
Hands-on skills	37 (69.8)	S3, S4, S7-S11, S15, S16, S18, S20, S21, S23-S25, S27-S30, S32-S34, S36-S38, S40-S50, S52
Mobilization of skills	32 (60.4)	S8 - S11, S15, S16, S18, S20, S21, S23, S24, S25, S27-S30, S32-S34, S36-S38, S40-S45, S48-S50, S52
Minds-on skills	20 (37.8)	S3, S15, S16, S19, S20, S23, S26, S28, S29, S35-S37, S41-S45, S48, S50, S52
Inquiry-based learning (IBL)	12 (22.6)	S4, S11, S21, S24, S27, S29, S34, S37, S38, S43, S51, S52
Learning through everyday experiences	4 (7.5)	S12, S29, S33, S35
Scientific communication	3 (5.7)	S4, S24, S27
Accessible alternative to learning	1 (1.9)	S19
Studies which did not address the concept of practical work	8 (15.1)	S3, S14, S17, S18, S22, S31, S39, S53

lastly, there are those that do not address the concept of practical work in a clear and unequivocal way (S3, S14, S17, S18, S22, S31, S39, S53), this category corresponding to 15.1% of investigations ($f = 8$).

Overall, the systematic literature review reveals that the concept of practical work is prominently assumed as a process that goes beyond allowing the development and improvement of practical skills associated with handling of laboratory material. It is above all, a method that allows the students to understand the nature of science by involving them in activities that mimic the action of scientific research processes. This understanding results from the construction and mobilization of scientific knowledge, through critical thinking capable of raising hypotheses and formulating ways to test them, simultaneously enabling the theoretical and conceptual reflection of the phenomena in question, in a minds-on approach.

3.2. Advantages of practical work

Regarding the advantages associated with the promotion of practical work, the content analysis of the different investigations of the *corpus* allowed a distribution of studies by five global categories, as specified in Table 6.

TABLE 6 Identified advantages in practical work.

Categories	f (%)	Studies
Development of research-based learning skills	37 (69.8)	S1, S4-S7, S11-S21, S24, S27-S30, S32, S34-S36, S38, S40-S45, S47, S50-S53
Emphasis on active student participation in the learning process	36 (67.9)	S1, S3-S5, S6-S10, S12, S16, S17, S19-S21, S23, S26-S31, S34, S36, S37, S41-S47, S49-S51, S53
Development of relevant knowledge about practical skills (hands on) and conceptual understanding (minds on)	30 (56.6)	S1, S2, S4, S6, S9-S12, S16, S19, S20, S24, S25, S27, S28, S30, S33-S36, S38, S40, S43-S48, S51, S52
Development of scientific literacy	21 (39.6)	S3, S7-S9, S12-S14, S22, S23, S27-S29, S34, S38, S40, S42, S44-S46, S48, S50
Preparation of students for practical assessments	4 (7.5)	S1, S14, S44, S46

In the first category and in 69.8% ($f = 37$) of the investigations, practical work is considered to allow the development of learning skills based on research processes (S1, S4-S7, S11-S21, S24, S27-S30, S32, S34-S36, S38, S40-S45, S47, S50-S53). This methodology presents the ability to make the contents more relevant to students, increasing their motivation and the emotion of discovery (S7), promoting positive attitudes toward science (S6), being, at the same time, able to increase their intrinsic motivation (S51). Likewise, the adoption of this methodology allows, through the dynamics developed in learning environments outside the classroom, the realization of on-site investigations on objects, tools, cases, and events that cannot be brought directly to school (S21).

Thus, practical work is considered the key to capturing and maintaining students' interest in science, encouraging them to continue their studies in this area (S1, S6, S12, S14, S16, S20, S24, S28, S29, S34, S38, S43, S44, S51, S52). As seen by many teachers, practical work is still an essential aspect of daily practice in science teaching, being essential for effective learning (S1). It allows the development of prediction, observation, and interpretation skills, which are transferable to new contexts (S47). It also provides immediate feedback (S14). Moreover, the fact that practical work stimulates an active and in-depth approach to learning, resulting from work sensitive to real problems related to everyday life (S5, S36, S45), is also seen as an important advantage, along with its ability to improve the dynamics of collaborative work (S7, S11).

Another study group (67.9%, $f = 36$) identifies the advantage of practical work to allow the active participation of the student in the learning process (S1, S3-S10, S12, S16, S17, S19-S21, S23; S26-S31, S34, S36, S37, S41-S47, S49-S51, S53). The conversations about learning activities during the practical work are of great importance, contributing to the improvement of communication skills (S26). It is also identified as an advantage that practical work allows the development of essential practical skills, which allow students to feel motivated to pursue scientific careers, giving them more confidence to study these areas at higher and more complex levels (S10). The development of practical work may also help students develop the capacity to construct mental models, about scientific phenomena that cannot be observed directly (S17) and may also manifest a significant impact on the emerging professional identities of students, as well as on their value charts, of eventual future science teachers (S31). Another notable advantage associated with practical work is that it can lead to better learning, as students are more likely to understand and remember actions they have taken, rather than actions they have been told to perform (S44).

The fact that practical work involves students in scientific themes, developing their relevant knowledge on these topics, hands on skills and conceptual understanding (minds on), involving students simultaneously in the process of building their own knowledge, in a constructivist perspective (S9, S19, S25) is pointed out by several publications (S1, S2, S4, S6, S9-S12, S16, S19, S20, S24, S25, S27, S28, S30; S33-S36, S38, S40, S43-S48, S51, S52), corresponding to a percentage of 56.6% ($f = 30$) of the studies analyzed. Practical work, particularly through laboratory work, also helps to understand the difference between observation and data presentation (S6). This methodology supports students' learning, motivating their involvement, while specific curricular requirements are met (S51). Here, it is also relevant that practical work allows improvement of teachers' knowledge and professional practice (S33).

For another group of authors (39.6%, $f = 21$), practical work emerges as a central strategy for the development of scientific literacy (S3, S7-S9, S12-S14, S22, S23, S27-S29, S34, S38, S40, S42; S44-S46, S48, S50). In this category, the studies emphasize understanding processes and concepts, helping to diagnose and correct students' misconceptions, as well as alternative conceptions, stimulating their curiosity (S3, S28). It is also highlighted the important contribute brought by practical work to the students' social development (S29). The development of critical and creative thinking is also highlighted as an important advantage. Practical work also contributes to the learning of the nature of science (S8, S9).

Finally, we group the studies (7.5%, $f = 4$) where the advantage of practical work is evidenced to assume a core role in the process of preparing students for the moments destined to practical evaluations (S1, S14, S44, S46).

3.3. Practical work evaluation

About the evaluation, there is a great dispersion of selected methodologies, which would initially be expectable due to the differentiated nature and scope of practical work, analyzed in each investigation that is integral to this systematic review. However, it is also possible to group the types/methodologies of practical work evaluation into a set of six unique categories, as illustrated in Table 7. In a first category and corresponding to 24.5% ($f = 13$) of the studies, there are investigations in which the evaluation of practical work takes place through a specific framework, that is, through an evaluation system whose structure includes a set of strategies and instruments, specially designed to allow the evaluation of a specific type of practical

TABLE 7 Practical work evaluation types/methodologies.

Categories	f (%)	Studies
Assessment through a specific framework	13 (24.5)	S7, S9-S11, S16, S20, S25, S28, S37, S41, S44, S46, S48
Theoretical and/or practical tests and worksheets	11 (20.8)	S8, S12, S14, S15, S17, S23, S27, S29, S39, S42, S47
Formative assessment approach	4 (7.5)	S13, S18, S19, S43
Assessment through the application of an instrument and/or participation of a specific agent	3 (5.7)	S16, S24, S49
Assessment carried out on the students' portfolio	1 (1.9)	S50
Unidentified assessment type	22 (41.5)	S1-S6, S21, S22, S26, S30-S36, S38, S40, S45, S51-S53

TABLE 8 Identified disadvantages in practical work.

Categories	f (%)	Studies
Teacher concerns and professional content knowledge issues	26 (49.1)	S1, S2, S4, S8, S10, S12, S17, S18, S23, S24, S26-S28, S31, S32, S34, S36, S38, S40, S41, S44, S46, S47, S50-S52
Distortion of purpose, triggered by evaluation processes	21 (39.6)	S2, S3, S6, S7-S10, S13, S16, S22, S25, S27, S34, S36, S39, S42, S45, S47, S48, S52, S53
Economic, organizational and environmental constraints	20 (37.7)	S1, S4, S14, S21, S29, S34, S36, S38, S40-S45, S47-S51, S53
Descriptive learning tasks in science "cookbook" style	18 (34.0)	S2, S4, S6-S8, S11, S15, S17-S19, S25, S26, S30, S33, S37, S39, S46, S52
Motivational effects	3 (5.7)	S1, S20, S43

work. The evaluation includes elements such as general settings, physical context, the relationship between skills and knowledge, and how realistic and interesting the task is for students (S7, S9-S11, S16, S20, S25, S28, S37, S41, S44, S46, S48).

Other authors (S8, S12, S14, S15, S17, S23, S27, S29, S39, S42, S47) perform the assessment through national tests/exams. The dominance of this type of evaluation is a factor that restricts the authentic nature of investigative science, which often follows strict and stereotyped routines, and having, also often, a test model influenced by national policies. This paradigm, leads students, at various times, to view practical work only as a way to obtain good marks, to the point that in certain situations they falsify the practical results obtained in an exam situation, in order to reach the expected results. Within the analyzed studies 20.8% ($f = 11$) are found within this category.

Another set of studies (7.5%, $f = 4$) favors formative evaluation (S13, S18, S19, S43). After the practical work activity there is room for discussion and explanation of a set of questions. The discussion focuses on various aspects of the practice such as forecasting, creating methods, problem solving, conclusions or phenomena explanations. Practical activities can benefit from a formative assessment approach when they foresee asking questions to students, which will be used to inform better learning and understanding of phenomena. The intention is to give students a reason to recapture the material and help them understand the limits of their own knowledge, starting from the basis of a summative assessment that educators can store, presenting evidence that students have properly performed a series of practical activities.

The evaluation of practical work is also done through the application of an instrument and/or participation of a specific agent (S16, S24, S49). In this category, which includes 5.7% ($f = 3$) of the studies, the evaluation may even include the involvement of an external examiner, whose function is to interview the students and examine their ability to perform laboratory tasks in the school context. Here is also the possibility of the evaluation going through the application of a specific instrument, aimed at evaluating the effect of laboratory experiences on the attitudes of students. Finally, it is also considered the possibility of developing a resource guide, in order to evaluate the scientific manipulative competencies of students in secondary schools.

The second to last category is filled solely with the S50 study (1.9%, $f = 1$), with the practical work evaluation being predicted through the student's portfolio of laboratory reports, conducted by the teacher and an external reviewer, or by a special case-based assignment in the national matriculation examination. The classification of this oral or written exam contributes to 25% of the students' final grade, while the other 75% is based on the information (i.e., reports, reflections, teacher evaluation) collected continuously in a personal portfolio.

Finally, the types/methodologies of evaluation that were not clearly identified and/or unequivocally presented were included (S1-S6, S21, S22, S26, S30-S36, S38, S40, S45; S51-S53), corresponding to a percentage of 41.5% ($f = 22$) of the studies.

3.4. Disadvantages of practical work

Regarding the disadvantages associated with the promotion of practical work, the content analysis of the different investigations of the *corpus* allowed a distribution of studies by five categories, as demonstrated in Table 8. In the first, corresponding to 49.1% ($f = 26$) of the studies, the disadvantages associated with teachers' concerns about the development of practical work are framed, as well as questions of knowledge of professional content (S1, S2, S4, S8, S10, S12, S17; S18, S23, S24, S26-S28, S31, S32, S34, S36, S38, S40, S41, S44, S46, S47, S50-S52). Thus, teachers have to consider various concerns related to fostering practical work, from management concerns, maximization of practical work with students, working with other teachers using effective laboratory methods, and also concerns related to the refinement of tasks, always having the development of students' skills in mind (S4).

On the other hand, there is also concern associated with the possibility of teachers being influenced by a powerful rhetoric that understands practical work as a universal panacea, that is, the educational solution for all learning problems in science (S8). This is particularly worrying, as teachers often reveal a lack of skills to effectively guide students in the conduct of practical work (S32). Despite the previously flagged gaps, teacher education and disciplinary curricula have been emphasizing the relevance of practical work, but not proceeding in the same way regarding the nuclear importance of clarification, on the meanings of words/concepts, during its performance.

It is possible to argue that the use of language for effective communication in the classroom (as a pedagogical competence) is not sufficiently emphasized in the initial training of science teachers, as well as in their professional development programs, reflecting this aspect in the frequency and quality of the dynamic of practical work (S26). In addition, there are also cultural questions about how adequately prepared students and teachers are, within their zone of proximal development, so that progress toward research learning practices (S2) is allowed.

Although a considerable part of practical work, associated with the encounter and interpretation of relationships, also involves the performance of an adequate data analysis, increasing competence in data analysis is rarely the central objective of practical work, and the lack of competence in this procedure, contributes to a limitation of learning outcomes (S28). Finally, in this category, another of the concerns pointed to the fostering practical work in science, results from a serious misalignment between the intended curriculum, and the one effectively implemented. This situation may be caused by the teachers' misinterpretation of a poorly elaborated global curriculum, making it necessary to make efforts to develop more effective curriculum designs. However noble the ideals of curriculum developers, if the formal curriculum is not clearly articulated, erroneous interpretations will occur, leading to the misalignment mentioned above (S27, S32, S34, S36, S47). In addition, instead of a teacher-centered curriculum, the design of a student-centered curriculum should be promoted according to a constructivist approach (S52).

Other studies (39.6%, $f = 21$) refer to the disadvantages of practical work for the distortion of its purpose, triggered by evaluation processes (S2, S3, S6, S7-S10, S13, S16, S22, S25, S27, S34, S36, S39, S42, S45, S47, S48, S52, S53). In this category, and from the point of view of the students, it is observed that their fundamental concern is the completion of the tasks associated with practical work, mainly due to evaluative questions. This concern can lead to a drastic reduction of any serious possibilities of effective learning (S13). Also due to a congested curriculum, and now from the point of view of teachers, the approaches associated with practical work can also be seen as implausible in the light of the evaluation (S2, S27, S34, S36, S47, S48).

Moreover, a major problem regarding the evaluation of laboratory performance is that such assessment rarely falls on the actual practical performance and is mainly based on the application of written tests (S10). It is also verified in this category that the occurrence of evaluation moments with greater weighting – such as national exams – distort the ways in which practical work has been used to facilitate teaching and learning in science classes (S39). For the evaluation to be effective, it is necessary to consider conceptual understanding, procedural understanding, procedural competences, or practical competences.

Procedural competencies are generalizable, transferable from one context to the other and readily applicable at any juncture. However, the term "practical skills" or "practical competencies," although often referred to in the literature on practical work, is rarely explicitly defined from the perspective of science teaching (S10). It is also considered that the fact that there are alternatives to practical tests in science, means that students can take exams without being exposed to practical work dynamics. This means that in this case, students will be less able to put the knowledge learned into practice, in order to solve real problems of their daily lives (S45).

In a third category and corresponding to a percentage of 37.7% ($f = 20$), there are studies which point to limitations based on economic, organizational and environmental restrictions (S1, S4, S14, S21, S29, S34, S36, S38, S40-S45, S47-S51, S53). It is verified that research learning is not as common in countries with few economic resources, because the implementation of practical work requires facilities with new and updated equipment, with an adequate space for effective participation in practical investigations – the laboratory. For this reason, funding limitations are pointed out - for cases where schools are unable to afford laboratory equipment and technical assistants - as a factor that can prevent teachers from performing practical work.

This situation, in turn, has the potential to contribute to a continuous disengagement with scientific courses, and their subsequent professional careers (S4, S36, S38, S45, S47). In line with these restrictions, the reason why practical work, such as field outings, is not often used in schools, may derive from the general idea that knowledge is acquired in the classroom, classically organized by teachers and students. Out-of-school experiences are often considered unimportant, and field trips have several limitations, such as: planning takes time; available transportation and accommodation budgets are often structured for only half day or at most one day; large classes; disturbance of compliance with the subject's "program"; the climatic instability associated with the exploitation of open spaces, in short, without a preliminary preparation the learning experiences can be quite limited (S21).

Regarding inquiry-based learning, it is found that the fact that it does not occur often in schools relates to the school learning environment that is often rigidly structured, not allowing students to engage in open investigations. These investigations are usually framed in a climate of uncertainty and unpredictability, and the classroom is often not adapted to its proper development. In addition to the situations previously mentioned, the school system also requires teachers to perform a large amount of work for evaluation purposes, and this discourages them from involving students in open and sometimes time-consuming investigations (S29).

Although practical work is often considered essential, it is also associated with concerns related to the risk of chemical hazard and environmental pollution, particularly in the teaching of Chemistry (S38). The problems also arise when the teacher has to deal with large classes, in classes of an investigative nature (S21, S53). Finally, there is also a permanent pressure to justify the continued inclusion of practical work at a time when greater resource management efficiency is required. This pressure becomes more significant in countries facing greater economic challenges (S1).

A set of studies (34%, $f = 18$) identifies limitations associated with the type of learning tasks, mostly descriptive, and with a "cookbook" style (S2, S4, S6-S8, S11, S15, S17-S19, S25, S26, S30, S33, S37, S39, S46, S52). The analysis of these studies allows us to determine that students can become frustrated in learning environments by research, not obtaining a greater conceptual understanding, when compared to direct instruction (S2). This is because, generally, the focus of teachers in practical classes is predominantly to develop scientific knowledge instead of developing scientific research skills, making practical work more effective in getting students to do what is intended, through the manipulation of physical objects, instead of making them mobilize scientific ideas and reflect on the data (S8).

Another limitation pointed to the development of practical work is that sometimes it can be applied so that students only follow the instructions given by the teacher, not needing to use creativity or critical thinking to process the information. In this case, practical work will constitute a waste of time, being confusing and counterproductive (S6). In addition, it can be criticized for not being consistent with the way scientists work, nor to demonstrate how to use scientific ideas to guide their actions, such as reflection on the data that are collected, summarizing only the description of what was done and what was observed (S19). It is increasingly recognized that scientific processes cannot be separated from scientific ideas, and this dialectical relationship between process and content has been accepted by most researchers (S33).

Finally, and corresponding to a percentage of 5.7% ($f = 3$), studies are grouped where limitations are essentially associated with the motivational effects that practical work triggers on students (S1, S20, S43). In this category, it can be seen that the real contributions of practical work are sometimes minimal, with regard to the acquisition of professional and personal skills, not contributing sufficiently to the motivation of students (S1) Students often only prefer practical work and group work when placed in comparison with other more theoretical teaching strategies (S20). Finally, if practical work is not properly performed, it may constitute a cause of stress or anxiety, which in turn can neutralize or prevent the potential educational benefits to be achieved by students (S43).

4. Conclusion

The systematic review of the literature allows us to perceive, with evidence, that the concept of practical work includes, more often, three great ideas: it should be integrator of the manipulation of materials in practical activities according to a *hands-on* approach; include the mobilization of competencies associated with scientific processes, addressing a better understanding of the nature of science; and mobilize scientific knowledge, in line with a *minds-on* approach. The main advantage of the use of practical work is the fact that it allows the development of practical skills in scientific processes and, at the same time, a central conceptual understanding, resulting from the fusion between the *hands-on* approach with the *minds-on* approach in the development of activities. This merger contributes to increasing the motivation for learning sciences, increasing the likelihood that more students will want to pursue a scientific career, which can have a very positive impact on the lack of human resources, which in certain contexts is felt in STEM areas. The second advantage associated with practical work is that researchers consider this methodology to be essential for the development of students' scientific literacy, with a significant impact on a better understanding of the concepts associated with the scientific phenomena under study. In this line, practical work contributes to the important mission of mitigating arguments, beliefs, and/or alternative conceptions, without scientific background, contributing to the formation of better-informed individuals, and able to apply critical thinking. The third major advantage is to enable the development of research skills, allowing students to be immersed in processes in everything similar to the research carried out by scientists, thus bringing them closer to a deeper understanding of their mission and their work in everyday life. This type of practical work will also depend on adequate teacher training.

The most significant practical work evaluation methodology consists of a type of evaluation carried out through a specific framework, using procedures specially designed for practical work to be developed in a specific context, and which focuses on a given phenomenon. In these cases, specially designed assessment tools are used and/or adapted to the specific situation concerned. Practical work is also evaluated through theoretical and/or practical tests and work forms. Training approaches that provide, for example, for discussion and explanation of a number of issues, as well as aspects associated with forecasting, the creation of methods, problem solving, discussion of conclusions or explanations of scientific phenomena, do coexist.

The great disadvantage of practical work is a consequence of the type of strategies adopted. If practical work is not properly conducted, it can easily become a methodology that is not in agreement with the way scientists develop their research, even transforming it into a practice that consists essentially of a mere description of what has been seen, and what has been accomplished, promoting overly descriptive and formatted activities in a "cookbook" style. A second criticism points out that it is difficult to perform the proper realization of practical work in the teaching of sciences in countries and in contexts with low economic resources. These financial difficulties have a direct impact on adequate training of human resources, preventing the development of the full potential of this methodology, also having an impact on the creation of appropriate spaces and infrastructures, such as laboratories and non-formal science education centers, and also impact on the ability to acquire materials and reagents for a proper equipping of these spaces.

The development of practical work with open investigations requires adequate areas and classes not very large, which is not the reality lived in many schools. On the other hand, the consumption of time and the amount of work associated with the evaluation process of activities of this nature discourages students and teachers. Fourthly and lastly, it is also verifiable that students are often more concerned with completing practical work, according to what they think is expected by the script/protocol or the teacher himself, thus blocking a good part of the learning opportunities and, consequently, deviating from and misrepresenting the main purpose of the role of practical work.

In conclusion, and particularly recovering the identification of the advantages and limitations associated with the development of practical work in science education, it should be noted that the effect of the advantages appears to be more significant, having the ability to overcome the limitations identified in the different studies of the corpus. In this sense, it is therefore important to mention that the investigations which recognized these disadvantages or limitations do not call into question the performance of practical work, given its enormous relevance in learning, doing, and understanding the nature of science. What the research, several times, put into question, are the form and conditions in which the practical work is carried out.

So, in simple terms, the great reflection that can be made, with a view of the future of practical science teaching is: How can we turn these limitations into opportunities? Although this is a complex challenge, evidence suggests that the answer lies, among other aspects, in the appropriate initial and in-service training of science teachers in this particular field. This is because if teachers are more confident in their professional content knowledge, also in the area of practical work, they will increase the range of appropriate strategies to adopt in their teaching practice, increasing the probability of this being positively reflected in students' academic performance.

In order to carefully investigate whether practical work is relevant and successful in science education, it is undoubtedly of interest to investigate the everyday reality of teachers and students, in order to apprehend their perception of the practical work relevance, whether the textbooks they use favor this methodology, if the curriculum is designed taking into account an adequate operationality of practical work, if there are opportunities for non-formal science education where practical work is carried out, if the assessment methodologies are adapted to the purposes of practical work, and if the human and material resources available in schools are also compatible with its appropriate implementation.

Lastly, practical work is considered to remain a methodology with high formative value, provided that there are resources to develop it and the orientation given to the various strategies is in accordance with its potential and limitations.

Author contributions

HO: conceptualization and writing – original sketch. JB: formal analysis and writing – review and edition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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