Notes (September 2017)

The Institute for Effective Education was funded by the Gatsby Charitable Foundation in 2015 to carry out a short small-scale systematic review of the literature and policy documentation around practical science work. The purpose was to inform the Good Practical Science project. This document lists the studies the IEE identified, and indicates how they were considered as part of the review.

The team carried out a Rapid Evidence Assessment (REA), based on the toolkit developed by the Government Social Research Service (GSR) to "provide a balanced assessment of what is already known about a policy or practice issue, by using systematic review methods to search and critically appraise existing research" ("Rapid Evidence Assessment Toolkit index," 2013). Further information about definitions and methodology are available in the REA report (Appendix 1) downloadable from this page: www.gatsby.org.uk/goodpracticalscience

'Purposes' lists various curriculum documents mapped to the purposes of practical science, and their sources.

'Studies', 'Reviews' and 'Opinion pieces' lists the various types of evidence identified within the Rapid Evidence Assessment and why they were included or excluded, as well as giving the source.

'March 2017' lists studies published after the literature search for the REA was completed, and hence are not discussed in the main report. However, the studies have been mapped to the five purposes outlined in the Good Practical Science final report (not those in the REA). Although there are many similarities between the two sets of purposes, the set in the REA was constructed from the available literature and does not reflect subsequent developments in thinking

Purposes

Country	Document	Purpose of practical science	Age of students	Other comments	URLs
Finland	National core curriculum for upper secondary schools/ 2003	• to understand the significance of experimentation and theoretical speculation in the formation of knowledge in science; • to understand how knowledge is built up in science through experimentation and related modelling; • to learn how to plan and carry out experiments concerning different phenomena, taking safety considerations into account; • to be able to interpret, assess, present and discuss information that students have acquired through experimentation; • to improve students' aptitude for scientific work, team behaviour and their ability to use different sources for the acquisition of scientific information and to assess information critically.	16 to 18	key word 'experimentation' is used instead of practical work in the document	http://www.oph.fi/download/47678_core_curricula_upper_secondary_education.pdf
Singapore	National curriculum and Science Syllabus Lower and Upper Secondary Normal (Technical)	• Scientific subjects are, by their nature, experimental. It is therefore important that the candidates carry out appropriate practical work to facilitate the learning of this subject. • to be able to select and organise techniques, apparatus and materials; take readings accurately; handle experimental data and observations; interpret and evaluate experimental results.	12 to 17	key word 'practical work'	http://www.moe.gov.sg/education/syllabuses/sciences/files/science-lower-upper-secondary-2014.pdf
Japan	Courses of Study in Japan/Science for Lower Secondary School	• To carry out observations and experiments concerned with physical phenomena, to enable students to learn observational and experimental skills, to develop the ability to give consideration to the results of observations and experiments, and to develop and express their own ideas, and at the same time, to enable students to understand familiar physical phenomena - FOR LOWER SECONDARY-	12 to 15	key word 'experiments, hands-on work'	http://www.mext.go.jp/english/elsec/1303755.htm
		• To enhance student's interest in nature and sense of inquiry, to enable them to carry out observations and experiments, and to develop attitudes and abilities to investigate scientifically, and at the same time, to deepen their understanding of natural events and phenomena, and to develop scientific views of nature. -FOR UPPER SECONDARY-	15 to 18		
		• To enable students to have hands-on experience on investigating concrete examples • There is also some emphasis on discovery-based learning with practical work			
Estonia	National curriculum for upper secondary schools (2011)	• There are specific practical work activities and related learning outcomes for each single topic of every natural science subject	15 to 18		http://www.ibe.unesco.org/curricula/estonia/er_usfw_2011_eng.pdf
		• to be able to analyse and interpret directly perceived phenomena, as well as phenomena imperceptible to our senses at the micro, macro and mega levels, and appreciate the role of models and their limitations in describing such phenomena			
		• to use scientific method to gather information and investigate problems, frame hypotheses, control variables, collect data/evidence through observations or experimentation, analyse and interpret results and present conclusions indicating the solution to the scientific problem as well as limitations and sources of error involved.			
		• find and use sources of scientific and technological information in Estonian and English, presented at the verbal, numerical or symbolic level and be able to critically evaluate and appreciate such information from both a personal and social viewpoint (There are many 'practical work' examples in which students were asked to search information from other sources like web, library etc)			
China- HK	National Curriculum and Syllabuses for secondary schools / Science secondary 4-6	• Practical work and scientific investigations are common activities in the learning and teaching of science subjects. They offer students 'hands-on' experience of exploring, and opportunities to show their interest, ingenuity and perseverance.	15 to 17		http://www.edb.gov.hk/en/curriculum-development/cs-sec-edu/curri-guides/index.html
		• One purpose of practical work is to improve students' practical skills related to scientific investigations			
		• Practical work may be used to develop students' understanding of the scientific concepts and principles involved, as well as their ability to handle and interpret data obtained in investigations			
		• The following principles can be used as a reference for planning the school-based senior secondary science curricula: plan and devise appropriate and purposeful learning and teaching materials, practical work, scientific investigations and projects to develop students' knowledge and understanding, skills and processes, values and attitudes, problem-solving skills, critical thinking skills, creativity, and strategies for learning how to learn			
China-HK	Syllabuses for secondary schools / Science secondary 1-3	• practical work is essential for students to gain personal experience of science through doing and finding out	12 to 14		http://www.edb.gov.hk/en/curriculum-development/cs-sec-edu/curri-guides/index.html
		• in order to improve students ability in defining problems, designing experiments to find solutions, and interpreting the results			
		• students should also come to be aware of the importance of being careful and accurate when doing practical work and handling measurements			
China-Shanghai	National curriculum for Science	• in secondary schools, science curriculum is divided into physics, biology, earth, and chemistry. They are all separated and there are independent curricula, however English versions do not exist.			N/A
		• There are some national standards for those curricula, however they are also only in Chinese.			
Poland	Ministry of Education Report on the system of education in Poland	Upon completion of a secondary education in science, students are expected to be able to demonstrate "scientific thinking", which is "the ability to use scientific knowledge in order to identify and solve problems, and the ability to formulate conclusions based on empirical observation related to nature and society".	13 to 19	secondary education is divided between "stage 3" lower secondary, and "stage 4" upper secondary	http://www.tandfonline.com/doi/pdf/10.1080/0965975930010203
Estonia	Natural Science Curriculum	The purposes of practical work are not separated from the general purposes of science teaching so it is very hard to identify which purposes are for practical science particularly and which ones are for other teaching approaches. Very many skills are associated with practical work although the ways in which those skills can be achieved through practical work (or through any other means of teaching) are not clear. There is a clear emphasis on scaffolding during both practical work and other teaching methods.	Up to age 17		http://www.ibe.unesco.org/curricula/estonia/er_befw_2011_eng.pdf
Canada	Ontario Curriculum	- provide students with direct experience of nature through age-appropriate activities where practical activities of students with natural objects or their models are important			http://www.edu.gov.on.ca/eng/curriculum/secondary/science.html
		- shape the internal studying motivation of the students through studies that are mostly active, student-oriented and problem-based.			
		"The students learn to identify and purposefully observe the animate and inanimate objects and phenomena of nature, gather and analyse data and draw conclusions on the basis of this data. Through practical activities, the students learn to find different solutions to problems and through decision making involving society-based perspectives, analyse their possible consequences."			
		Practical science is intended to help students to develop four sets of skills of scientific investigation;			
		• initiating and planning			
		• performing and recording			
		• analysing and interpreting			
		• communicating			

Vietnam	Ng, W., & Nguyen, V. T. (2006). Investigating the Integration of Everyday Phenomena and Practical Work in Physics Teaching in Vietnamese High Schools. International Education Journal, 7(1), 36-50.	o Activeness o Voluntariness o Initiative o Creativity • To develop critical thinking • To generate enthusiasm for the sciences	secondary education: 11-15, high school: 15-18		http://eric.ed.gov/?id=EJ847202
South Korea	Swain, J., Monk, M., & Johnson, S. (1999). A comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK. International Journal of Science Education, 21(12), 1311-1323.	• To develop scientific thinking • Improve critical reasoning • Develop students' abilities to use research methods • Build capacity of students to act as reasonable citizens in everyday life	13-19		http://www.tandfonline.com/doi/abs/10.1080/095006999290093
	Kang, S., Scharmann, L. C., & Noh, T. (2005). Examining students' views on the nature of science: Results from Korean 6th, 8th, and 10th graders. Science Education, 89(2), 314-334.				http://www.researchgate.net/profile/Lawrence_Scharmann/publication/229882573_Examining_students'_views_on_the_nature_of_science_Results_from_Korean_6th_8th_and_10th_graders/links/543fc80d0cf21227a11b7cc8.pdf
	Kim, H.-B., Fisher, D. L., & Fraser, B. J. (2010). Classroom Environment and Teacher Interpersonal Behaviour in Secondary Science Classes in Korea. Evaluation & Research in Education				http://www.tandfonline.com/doi/abs/10.1080/09500790008666958
	Shim, K.C.; Moon, S.H.; Kil, J.H. and Kim, K (2014). 'Secondary Science Teachers' Views about Purposes of Practical Works in School Science'. International Journal of Social, Education, Economics and Management Engineering, 8(7), pp. 2131-2134				http://www.waset.org/publications/9998785
IGCSE	2015 Syllabus	Experimental work within science education • gives candidates first-hand experience of phenomena • enables candidates to acquire practical skills • provides candidates with the opportunity to plan and carry out investigations into practical problems.			http://www.cie.org.uk/images/128426-2015-syllabus.pdf
International Baccalaureate	IBO curriculum http://www.ibo.org/en/programmes/diploma-programme/curriculum/sciences/chemistry/	The sciences are taught practically. Students have opportunities to design investigations, collect data, develop manipulative skills, analyse results, collaborate with peers and evaluate and communicate their findings. The investigations may be laboratory based or they may make use of simulations and databases. Students develop the skills to work independently on their own design, but also collegiately, including collaboration with schools in different regions, to mirror the way in which scientific research is conducted in the wider community.	16 to 19		http://www.ibo.org/en/programmes/diploma-programme/curriculum/sciences/chemistry/
England	Science programmes of study: key stage 3 National curriculum in England	Most of the learning about science should be done through the use of first-hand practical experience and students must be able to: • ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience • select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate • make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements	11 to 14		https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335174/SECONDARY_national_curriculum_-_Science_220714.pdf
	Science programmes of study: key stage 4 National curriculum in England	• recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative • make and record observations and measurements using a range of apparatus and methods • evaluate methods and suggesting possible improvements and further investigations.	14 to 16		https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381380/Science_KS4_PoS_7_November_2014.pdf
Scotland	Curriculum for Excellence - Sciences: Principles and practice	• to develop skills of scientific inquiry and investigation • to motivate for progressively developing skills, knowledge, understanding and attitudes • to develop understanding of scientific concepts	3 to 18	Scotland does not have a curriculum in the traditional sense. They have Curriculum for Excellence which aims to achieve a transformation in education in Scotland by providing a coherent, more flexible and enriched curriculum from 3 to 18 but it is not a curriculum as such. It does not provide a prescriptive list of topics should be taught or at what stage those topics should be taught. It was introduced in August 2010. We used the principles and practice in Science and Good Practice in Science documents. They touch upon the purposes of practical work within the curriculum area and offer guidance on aspects of learning and teaching as well as assessment.	https://www.educationscotland.gov.uk/Images/sciences_principles_practice_tcm4-540396.pdf http://www.educationscotland.gov.uk/Images/Science3to18v4_tcm4-731895.pdf
	Curriculum for Excellence - Good Practice Examples	• to develop team working skills • to improve practical skills and have knowledge of up-to-date equipment • (with appropriate following discussions) to be able to access a conceptually difficult area of the sciences			
Wales	Science in National Curriculum for Wales: Key Stages 3-4	• to develop students' practical, problem solving and enquiry skills • to be able to plan to test a scientific idea, answer a scientific question, solve a scientific problem, and collect data from primary or secondary sources • to support working accurately and safely both individually and with others • to have an opportunity to evaluate methods of collection of data and consider their validity and reliability as evidence	11 to 16		http://learning.gov.wales/docs/learningwales/publications/140624-science-in-the-national-curriculum-en.pdf

N. Ireland	Northern Ireland National Curriculum: Science Key Stage 3-4	• to increase motivation, support collaborative working and connect learning about Science to the real world	11 to 16		http://www.nicurriculum.org.uk/docs/key_stage_3/areas_of_learning/non_statut
		• to develop students' thinking skills and personal capabilities			http://ccea.org.uk/curriculum/key_stage_3
		• to develop a range of practical skills when undertaking experiments, including the safe use of scientific equipment			http://ccea.org.uk/curriculum/key_stage_4
		• to develop inquiry skills such as planning investigations, collecting appropriate data and reporting			

Studies

Article	Statement of purpose	Methodology	Country	Age of students	Key findings	Incl/excl & why	Other comments	URLs
AAPT. (1998). Goals of the introductory physics laboratory. American Journal of Physics, 66(6), 483-486.	To establish generally accepted goals for using laboratories in teaching physics	Discussions with experts in physics education and expert physics teachers	USA	16 and above	The report suggested five categories for the purposes of practical work in physics teaching which are 1) The art of experimentation; 2) Experimental and analytical skills; 3) Conceptual learning; 4) Understanding the basis of knowledge in physics; 5) Developing collaborative learning skills.	Recommend inclusion: the report is an important contribution to attempts to categorise the purposes of practical work	This publication was not the outcome of a Delphi study of the expert community but it was rather the outcome of discussions held among the members of the committees involved in an official meeting.	http://www.aapt.org/Resources/policy/goaloflabs.cfm
Abdullah, M., Mohamed, N., & Ismail, Z. H. (2009). The effect of an individualized laboratory approach through microscale chemistry experimentation on students' understanding of chemistry concepts, motivation and attitudes. Chemistry Education Research and Practice, 10, 53-61	To investigate whether the use of an individualized approach through microscale chemistry experiments in secondary schools can increase students' understanding of chemistry concepts, improve attitude towards chemistry practical work and motivation.	experimental design with pre-test post-test / Two comparable groups of Form Four students (16 years old) participated. The students in the experimental group (83) worked individually on ten microscale chemistry experiments, whereas the control group (87) worked in groups on traditional experiments both for a period of 8 weeks. Pre and post tests were conducted before and after the treatment for both groups. Four instruments: chemistry concept tests, attitude towards chemistry laboratory work questionnaire, motivation questionnaire and interviews. Both the pre and post tests consisted of 25 multiple-choice and two structured questions based on the Form Four chemistry syllabus and covered the first three topics: introduction to chemistry, structure of the atom and formula and chemical equations.	Malaysia	16	the microscale approach can increase understanding of chemistry concepts, however, there was no significant difference in attitude and motivation among the students. Teachers and students both had a positive view of microscale experiments. Suggests microscale approach does not compromise understanding and attitudes/motivation, but saves on resourcing.	Recommend inclusion: paper is a robust assessment of the impact of individualising practical work		http://pubs.rsc.org/en/Content/ArticleLanding/2009/RP/B901461F#!divAbstract
Abrahams, I. and Reiss, M. J. (2012), Practical work: Its effectiveness in primary and secondary schools in England. J. Res. Sci. Teach., 49(8) 1035–1055.	Report of the baseline stage of the evaluation of a national project (Getting Practical: Improving Practical Work in Science—IPWiS) designed to improve the effectiveness of practical work in both primary and secondary schools in England.	A multi-site case study approach (10 primary schools, 20 secondary; 857 students) employing a condensed fieldwork strategy was used in which data were collected, using audiotape-recorded discussions, interviews, and observational field notes.	England	11 to 18	In both primary and secondary schools, the widespread use of highly structured "recipe" style tasks meant that practical work was highly effective in enabling students (n = 857) to do what the teacher intended. Whilst tasks in primary schools tended to be shorter than in secondary schools, with more time devoted to helping students understand the meaning of new scientific words, neither primary nor secondary teachers' lesson plans incorporated explicit strategies to assist students in making links between their observations and scientific ideas.	Recommend inclusion	Rich detail from the case study schools although unclear how schools, teachers, students chosen. No quantitative component. Read in conjunction with Abrahams, Reiss & Sharpe (2014)	http://onlinelibrary.wiley.com/doi/10.1002/tea.21036/abstract
Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. International Journal of Science Education, 30(14), 1945-1969.	The purpose of the study is to measure how effective practical work, as it is actually carried out in science classes in England for 11 year-old to 16 year-old students, is in enhancing students' knowledge and understanding, either of the natural world or of the processes and practices of scientific enquiry (p.1946-47).	Study based on the analysis of a sample of 25 'typical' science lessons in 8 different schools involving practical work in English secondary schools. Data took the form of observational field notes and tape-recorded interviews with teachers and students. The analysis used a model of effectiveness based on the work of Millar et al. and Tiberghien". (p. 1945)	England	11 to 16 year olds	The teachers' focus in the lessons observed "was predominantly on developing students' substantive scientific knowledge, rather than on developing understanding of scientific enquiry procedures. Practical work was generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect. There was little evidence that the cognitive challenge of linking observables to ideas is recognized by those who design practical activities for science lessons. Tasks rarely incorporated explicit strategies to help students to make such links, or were presented in class in ways that reflected the size of the learning demand." (p. 1945)	Recommend inclusion: Not only does the piece provide a detailed overview of multiple sources and their take on the purpose of practical work in science education, but the authors' own surveys also contribute to an understanding of the limitations of practical work when it is not tied explicitly to demonstrable learning outcomes.	Many useful observations. However, we need to comment on quality of study: 8 schools approached - no detail of how selected. Nor of how lesson observed chosen, beyond availability of teacher for pre/post interview. Student interviewing v ad hoc. No interview schedules provided.	http://www.rhodes.aegean.gr/ptde/labs/lab-fe/downloads/cti/Does_Practical_Work.pdf
Abrahams, I., & Saglam, M. (2010). A study of teachers' views on practical work in secondary schools in England and Wales. International Journal of Science Education, 32(6), 753-768.	This study examined whether there had been any changes in the relative importance of the aims science teachers assign to the use of practical work, across the full secondary age range (11–18), since the last such national survey undertaken by Kerr 46 years ago.	A stratified sample of representative schools was used in which 912 teachers were sent a questionnaire on their views towards the use of practical work in science with a total of 393 responses (42.5%) received.	England and Wales	Secondary (11-18) teachers were surveyed	Whilst there have been substantial changes in teachers' views about the relative importance of ten defined aims of practical work at Key Stages 4 and 5 (age 15–18) there have been no substantial changes at Key Stage 3 (age 11–14).	Recommend exclusion: the study makes statistical comparison of teachers' views vs 46 years ago rather than clear explication of the current rank order. Its results are also specific to the England & Wales context so hard to generalise.		http://www.tandfonline.com/doi/abs/10.1080/09500690902777410
Abrahams, I; Reiss, M. J & Sharpe, R. (2014) The impact of the 'Getting Practical: Improving Practical Work in Science' continuing professional development programme on teachers' ideas and practice in science practical work, Research in Science & Technological Education, 32:3, 263-280, DOI: 10.1080/02635143.2014.931841	To evaluate the impact of the Getting Practical: Improving Practical Work in Science CPD programme on teachers' ideas and practice in science practical work in primary and secondary schools in England.	The study employed a condensed fieldwork strategy with data collected using interviews, observational field notes and pre- and post-CPD training observations in practical lessons within 20 schools (from original baseline of 30).	England	8 primary (students aged 5–11 years) 12 secondary (students aged 11–18 years)	Whilst the CPD programme was effective in getting teachers to reflect on the ideas associated with the Getting Practical programme, it was much less effective in bringing about changes in actual teaching practice.	Recommend inclusion: the study provides useful insight about how teachers might be assisted in engaging their students in school science laboratory experiences	The CPD programme analysed was very short and it is hard to relate observed changes directly to the CPD programme itself. The research sample has suffered considerable attrition since the baseline (from 30 to 20 schools) and there is no detail of how observed lessons were chosen: both of these may be sources of bias.	http://dx.doi.org/10.1080/02635143.2014.931841
Apedoe, X. S., & Schunn, C. D. (2013). Strategies for success: uncovering what makes students successful in design and learning. Instructional Science: An International Journal of the Learning Sciences, 41, 773-791.	This study takes a first step at systematically delving into the issue of bridging the design–science gap by examining the problem-solving strategies that students are using when they solve a prototypical design task.	Videotaped performance assessments of high and low performing teams were analysed in depth.	USA	12 to 17	The strategies commonly associated with success in science (e.g., control of variables) did not necessarily lead to success in design. In addition, while both science reasoning strategies and design–focused strategies led to content learning, the content learned was different.	Recommend exclusion: the study does not particularly focus on practical work in science but focuses on design activities which does not necessarily to be in science subjects		http://link.springer.com/article/10.1007/s11251-012-9251-4#page-1

Bleicher, R. E. (1996), High school students learning science in university research laboratories. J. Res. Sci. Teach., 33: 1115–1133.	This article reports on a case study of a high school student working as an apprentice in a university research laboratory, part of a larger project aimed at evaluating a summer science program. The study examined communication between mentors (scientists) and student and how it constrained or supported learning.	Narrative summaries of the context and range of activities in which the student engaged, transcripts of talk, and excerpts from field notes are reported to support the view of the laboratory as a cultural system.	Australia	15	The student learned to participate in activities and discourse that were part of the everyday practices of members of a research laboratory. Mentors' instructional styles affected both the manner in which the student learned and how he talked about science in public presentations. As programs involving students in research laboratories are becoming more commonplace, it is important to understand the educational opportunities afforded. Further, what high school students are capable of doing and learning in research laboratories has implications for expanding learning goals in the school science curriculum.	Recommend exclusion: the study investigates one single student and the results cannot be generalised		http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1098-2736(199612)33:10%3C1115::AID-TEA5%3E3.0.CO;2-V/abstract
Bradley, J. D. (2001). UNESCO/IUPAC–CTC Global program in microchemistry. Pure Applied Chemistry, 73(7), 1215–1219	To investigate the microchemistry program which started four years ago and aims to promote a small-scale, low-cost approach.	Observations of the pilot applications of the microchemistry programme. Descriptive and limited assessments (as acknowledged by authors)	South Africa	N/A	The microchemistry has been received enthusiastically in nearly 40 countries now, and pilot projects have been initiated in several of these.	Recommend inclusion: Although the study is not a robust investigation of the microchemistry approach, it is valuable to recognise the needs and expectations of practical work applications in under-developed countries		http://www.iupac.org/publications/pac/73/7/1215/
Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. Journal of Research in Science Teaching, 42(3), 337–357	This study examined the impact of an inquiry-based instructional intervention on (a) children's ability to conduct science inquiry overall and to use specific skills in inquiry, and (b) narrowing the gaps in children's ability among demographic subgroups of students	All sessions were audiotaped, videotaped, and transcribed. experimental design / To determine the impact of the instructional intervention on students' ability to conduct inquiry and use the specific skills of the inquiry framework, paired samples t tests were conducted with the responses of the 25 students who completed both pre- and post- elicitations (individually administered practical assessments).	USA	9 to 13	Quantitative results demonstrated that the intervention enhanced the inquiry ability of all students regardless of grade, achievement, gender, ethnicity, socioeconomic status (SES), home language, and English proficiency. Particularly, low-achieving, low-SES, and English for Speakers of Other Languages (ESOL) students made impressive gains.	Recommend inclusion	small sample size; no comparison group; oral not written assessment; no record of teacher implementation fidelity.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20053/abstract
Dlodlo, N., & Beyers, R. N. (2014). The Experience of South African High-School Girls in a Fab Lab Environment. Pretoria: African Advanced Institute for Information Communication Technologies.	To investigate the impact of hands-on learning in women's education in South Africa	One session of 16 Grade 11 girls doing Fab Lab - observations and interviews. The methodology was based on a real world situation and a hands-on approach.	South Africa	Grade 11 (16-17?)	Both problem-solving activities and discussions stimulate situational interest. Problem-solving has the potential to make learners aware of their own inadequacies and inconsistencies of their previous knowledge of a topic, thus increasing covert or overt activity aimed at exploring concepts and ideas further. When discussing, learners are engaged in a task that allows them to express their ideas and reflections freely. The Fab Kids learning approach is a classic case of peer mentoring. Peer mentoring involves students helping each other to learn where the responsibility for teaching and learning is placed on learners. Positive experiences predominate in such an environment. The positive aspects include enhancement of learning skills/ intellectual gains and personal growth. Fab Lab participants acquired a number of skills including computer-aided design, research skills, communication skills, teamwork skills, technical drawing skills, writing skills and problem-solving skills. Exposure to technology enhanced the girls' confidence in being able to handle technology-related tasks.	Recommend exclusion: The study deals predominantly with engineering, and so is not directly relevant, though findings may be relevant to the development section of the report.		http://researchspace.csir.co.za/dspace/handle/10204/3542
Freedman, M. P. (1997). Relationship among laboratory instruction, attitude towards science, and achievement in science knowledge. Journal of Research in Science Teaching, 34(4), 343-357.	To investigate the use of a hands-on laboratory program as a means of improving student attitude toward science and increasing student achievement levels in science knowledge.	20 physical science classes. 36 weeks. One lab experience a week or no lab experiences (control). Using a post-test-only control group design, curriculum referenced objective examinations were used to measure student achievement in science knowledge, and a post-test Q-sort survey was used to measure student attitude toward science. A one-way analysis of variance compared the groups' differences in achievement and attitude toward science. Analysis of covariance was used to determine the effect of the laboratory treatment on the dependent achievement variable with attitude toward science as the covariable.	USA	14 to 18	The findings showed that students who had regular laboratory instruction: (a) scored significantly higher ($p < .01$) on the objective examination of achievement in science knowledge than those who had no laboratory experiences; (b) exhibited a moderate, positive correlation ($r = .406$) between their attitude toward science and their achievement; and (c) scored significantly higher ($p < .01$) on achievement in science knowledge after these scores were adjusted on the attitude toward science covariable.	Recommend inclusion: The study is clear in terms of which purposes of practical work are being investigated and uses robust statistical tests to compare differences	Control group. Same textbook used.	http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1098-2736(199704)34:4%3C343::AID-TEA5%3E3.0.CO;2-R/abstract
Hart, C., Mulhall, P., Berry, A., Loughran, J. and Gunstone, R. (2000), What is the purpose of this experiment? Or can students learn something from doing experiments?. J. Res. Sci. Teach., 37: 655–675.	Describes a unit of laboratory work which was unusual in that the teacher's purpose was to develop students' understanding about the way scientific facts are established with little expectation that they would understand the science content involved in the experiments.	Year 10 in all-girls school (n=30). Mixed method approach The data sources were: * classroom observation, and field notes documenting these, throughout the unit of work (lessons over a 6-week period) * paper and pencil class survey administered about half way through the unit (n.22) (see Appendix A) * copies of all student work (including laboratory ``reports'') (n.30) * individual student interviews at the completion of the unit focusing on students' perceptions of the purpose of the task (n.10, randomly selected) * laboratory group interviews post unit of work (see Appendix B) (laboratory groups, n.4 out of a possible 10 groups; approx. 3 students per group) audiotaped / each analysed appropriately.	Australia	14 to 15	The unit was very successful from both a cognitive and affective perspective. An important feature was the way in which students gradually came to understand the teacher's purpose as they proceeded through the unit. Authors say there is a danger of over-claiming for practical work and need to manage expectations.	Recommend inclusion	No comparison group; small-scale; first-named author was teacher involved and had a clear agenda.	http://onlinelibrary.wiley.com/doi/10.1002/1098-2736(200009)37:7%3C655::AID-TEA3%3E3.0.CO;2-E/abstract
Haslam, C. Y., & Hamilton, R. J. (2010). Investigating the use of integrated instructions to reduce the cognitive load associated with doing practical work in secondary school science. International Journal of Science Education, 32(13), 1715-1737.	This study investigated the effects of integrated illustrations on understanding instructions for practical work in science.	Experimental design with pre-test post-test. Ninety-six secondary school students who were unfamiliar with the target content knowledge and practical equipment took part. 46 modified, 50 conventional (control) instruction.	New Zealand	13 to 18	Modified instructions produced significantly higher levels of performance on task, lower time to completion and perceived cognitive load and task difficulty, higher relative efficiency score, and higher post-test scores than the conventional instructions.	Recommend inclusion	Teachers who didn't want to take part were put in the control group.	http://dx.doi.org/10.1080/09500690903183741

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. Journal of Research in Science Teaching, 42(7), 791–806	This study focuses on the ability of high-school chemistry students, who learn chemistry through the inquiry approach, to ask meaningful and scientifically sound questions.	Experimental design with 6 classes and 11 students total (55 intervention and 56 control students) over 2 years. Assessed by questionnaire after a practical and reading a scientific journal article./ The three common features investigated were (a) the number of questions that were asked by each of the students, (b) the cognitive level of the questions, and (c) the nature of the questions that were chosen by the students, for the purpose of further investigation. questionnaires used in the study were designed by the researchers	Israel	11 to 18	It was found that students in the inquiry group who had experience in asking questions in the chemistry laboratory outperformed the control grouping in their ability to ask more and better questions.	Recommend inclusion	Assessment inherent to treatment (i.e. intervention group had practice posing higher-order questions). Small sample of teachers involved and little about implementation fidelity. But promising evidence to support further investigation.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20072/abstract
Jaakkola, T., & Nurmi, S. (2008). Fostering elementary school students' understanding of simple electricity by combining simulation and laboratory activities. Journal of Computer Assisted Learning, 24(4), 271–283	The aim of this experimental study was to investigate if it would be more beneficial to combine simulation and laboratory activities than to use them separately in teaching the concepts of simple electricity.	Experimental, pre-test post-test design / Matched by pre-test performances, 66 elementary school students from one elementary school were placed into three different learning environments: computer simulation, laboratory exercise and a simulation–laboratory combination. Intervention was 2 hour session. Students worked in pairs. Post-test completed day after. Pre-tests were Raven's Matrices for educative ability and basic domain-specific subject knowledge; post-test was basic subject knowledge repeat plus more advanced questions.	Finland	10 to 11	The results showed that the simulation–laboratory combination environment led to statistically greater learning gains than the use of either simulation or laboratory activities alone, and it also promoted students' conceptual understanding most efficiently.	Recommend inclusion	Post-test day after - no legacy effect. Small sample sizes.	http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2729.2007.00259.x/abstract;jsessionid=A53A941472E09FE4C7493C4671176895.f04t01?deniedAccessCustomisedMessage=&userIsAuthenticated=false
Jordan, R. C., Ruibal-Villasenor, M., Hmelo-Silver, C. E. and Etkina, E. (2011), Laboratory materials: Affordances or constraints?. J. Res. Sci. Teach., 48: 1010–1025.	This study investigates the role of timing and availability of laboratory equipment in the context of two different laboratory exercises.	Uses both case study and an experimental approach / investigate how laboratory materials guide the planning, context, creativity, and timing of ideas shared among students using comparison tests and coding techniques	USA	undergrads	Data support the notion that providing students with laboratory equipment before students plan and consider different experimental approaches can constrain students' ideas and encourage tool-focused solutions to experimental design tasks.	Recommend exclusion: not school age		http://onlinelibrary.wiley.com/doi/10.1002/tea.20418/abstract
Kanari, Z. and Millar, R. (2004), Reasoning from data: How students collect and interpret data in science investigations. J. Res. Sci. Teach., 41: 748–769.	This study explored the understandings of data and measurement that school students draw upon, and the ways that they reason from data, when carrying out a practical science inquiry task (comparing covariation - i.e. indep variable covaries with dep variable - and non-covariation - where it doesn't).	60 students from 6 schools. video recording analysis, thematic coding of interviews	England	10 to 14	An analysis of the sample students' performance on the practical tasks and their interview responses showed few differences across task contexts, or with age, in students' reasoning, but significant differences in performance when investigating situations of covariation and non-covariation. Few students in the sample displayed sufficient understanding of measurement error to deal effectively with the latter. Investigations of non-covariation cases revealed, much more clearly than investigations of covariation cases, the students' ideas about data and measurement, and their ways of reasoning from data. Such investigations therefore provide particularly valuable contexts for teaching and research	Recommend inclusion	Rich qualitative data with emphasis on how students analyse data from practicals.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20020/abstract
Kang, S., Scharmann, L. C., & Noh, T. (2005). Examining students' views on the nature of science: Results from Korean 6th, 8th, and 10th graders. Science Education, 89(2), 314-334.	To explore the opinions of secondary school students on the nature and purposes of science	A multiple choice questionnaire administered to 1702 Korean students	South Korea	Years 6, 8 and 10	The results indicated some inaccurate views on the theories and nature of science among students	Recommend exclusion: use for Korean case study only (insufficient focus on practical science).		http://onlinelibrary.wiley.com/doi/10.1002/sce.20053/abstract
Keys, C. W., Hand, B., Prain, V. and Collins, S. (1999), Using the Science Writing Heuristic as a Tool for Learning from Laboratory Investigations in Secondary Science. J. Res. Sci. Teach., 36: 1065–1084	This article presents and discusses preliminary research on a new heuristic tool for learning from laboratory activities in secondary science.	One teacher, 2 classes with in-depth study of four small groups. Interpretive techniques using audio and video recordings, pre-study questionnaires and students' written reports.	Greece	13 to 14	There is evidence that use of the science writing heuristic facilitated students to generate meaning from data, make connections among procedures, data, evidence, and claims, and engage in metacognition. Students' vague understandings of the nature of science at the beginning of the study were modified to more complex, rich, and specific understandings.	Recommend inclusion	No comparison group so relative impact unclear. Heuristic was combined with use of small group discussion etc which has shown to be effective in learning, so confounding variables.	http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1098-2736(199912)36:10%3C1065::AID-TEA2%3E3.0.CO;2-I/abstract
Kim, H.-B., Fisher, D. L., & Fraser, B. J. (2010). Classroom Environment and Teacher Interpersonal Behaviour in Secondary Science Classes in Korea. Evaluation & Research in Education, 14(1), 3-22.	The three objectives of the study were to provide validation data for the Korean versions of the WIHIC and QTI, investigate associations between students' attitude to science and their perceptions of the classroom environment as assessed by the WIHIC and the QTI, and investigate gender-related differences in the students' perceptions	The questionnaires were administered to 543 students in 12 different Korean schools. The cross-cultural validity of the WIHIC and the QTI was supported.	South Korea		There were positive relationships of classroom environment and interpersonal teacher behaviour with students' attitudinal outcome. Relative to girls, boys perceived their learning environments and their teachers' interpersonal behaviour more favourably and reported more favourable attitudes toward their science classes. Generally, students' perceptions of the learning environment and the teachers' interpersonal behaviour suggest that students should receive more teacher support and involvement in the teaching/learning process and cooperate with other students more than at present.	Recommend exclusion: use for Korean case study, but content not relevant for general review (not focused on practical science)		http://www.tandfonline.com/doi/abs/10.1080/09500790008666958#.VRhjBfnF9i8

Marcus, N., Cooper, M., & Sweller, J. (1996). Understanding instructions. Journal of Educational Psychology, 89(1), 49-63	This paper explores students' understanding of instructions within the context of cognitive load theory	Experimental design with pre-test post-test / The participants were 30 Year 6 students (equivalent to U.S. sixth graders) from a Sydney primary school. They had no previous experience in the subject area of electricity or with connecting together electrical resistors. 15 had diagrammatical instructions, 15 textual.	Australia	11 to 15	Results suggested that understanding depends on the degree of interaction among elements of information. However, if interacting elements can be incorporated into a diagrammatic schema, cognitive load will be reduced and understanding enhanced.	Recommend inclusion: it provides good guidance for how the instructions of practical work should be prepared		http://psycnet.apa.org/journals/edu/88/1/49/
McCarthy, C. B. (2005), Effects of thematic-based, hands-on science teaching versus a textbook approach for students with disabilities. J. Res. Sci. Teach., 42: 245–263.	This study describes a program in which 18 middle school students with serious emotional disturbances were instructed, over the course of 8 weeks, on "Matter" using one of two different instructional approaches.	Statistical comparison of pre and post tests using linear regression methods and thematic coding to compare qualitative responses	USA	12 to 15	Results indicate that, overall, students in the hands-on instructional program performed significantly better than the students in the textbook program on two of three measures of science achievement, a hands-on assessment and a short-answer test. The students did not differ on a multiple-choice format test. With regard to behaviour, there were no significant differences in behavioural problems found between the two groups of students over the course of the study.	Recommend inclusion	Small scale.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20057/abstract
Moeed, A. (2011). Successful science learning from practical work. School Science Review, 93(343), 121-126	Aims to investigate whether practical work is an effective tool in teaching science in schools	273 Year 10 students. Survey design. A questionnaire was used so that data could be collected from an entire cohort in one school, with little disruption to the teaching and learning. The questionnaire sought both quantitative and qualitative responses.	New Zealand	14 and 15	The findings of the empirical research carried out in New Zealand described here are that students do learn and develop science understanding through engaging in practical experiences, which is in contrast with the current view that learning through practical work is inadequate and often less effective than desired.	Recommend inclusion (with caution)	Research uses survey approach in the investigation of learning which can be misleading in the sense that it is solely opinion-based, and this survey only featured one school which may have been unusual in the heavy emphasis it placed on practical work.	http://eric.ed.gov/?id=EJ963145
Mulopo, M. M., & Fowler, H. S. (1987). Effects of traditional and discovery instructional approaches on learning outcomes for learners of different intellectual development: A study of chemistry students in Zambia. Journal of Research in Science Teaching, 24(3), 217-227.	This study examined the differential effectiveness of traditional and discovery methods of instruction for the teaching of science concepts, understandings about science, and scientific attitudes, to learners at the concrete and formal level of cognitive development.	The dependent variables were achievement, understanding science, and scientific attitude; assessed through the use of the ACS Achievement Test (high school chemistry, Form 1979), the Test on Understanding Science (Form W), and the Test on Scientific Attitude, respectively. Mode of instruction and cognitive development were the independent variables. Subjects were 120 Form IV (11th grade) males enrolled in chemistry classes in Lusaka, Zambia. Sixty of these were concrete reasoners (mean age = 18.23) randomly selected from one of the two schools. The remaining 60 subjects were formal reasoners (mean age 18.06) randomly selected from a second boys' school. Each of these two groups was randomly split into two subgroups with 30 subjects. Traditional and discovery approaches were randomly assigned to the two subgroups of concrete reasoners and to the two subgroups of formal reasoners. Prior to instruction, the subjects were pretested using the ACS Achievement Test, the Test on Understanding Science, and the Test on Scientific Attitude. Subjects received instruction covering eight chemistry topics during approximately 10 weeks. Post-tests followed using the same standard tests.	Zambia	High school students	The traditional group outperformed the discovery group in achievement scores. It was concluded that the traditional approach might be an efficient instructional mode for the teaching of scientific facts and principles to high school students, while the discovery approach seemed to be more suitable for teaching scientific attitudes and for promoting understanding about science and scientists among formal operational learners.	Recommend inclusion		http://onlinelibrary.wiley.com/doi/10.1002/tea.3660240303/abstract
Ng, W., & Nguyen, V. T. (2006). Investigating the Integration of Everyday Phenomena and Practical Work in Physics Teaching in Vietnamese High Schools. International Education Journal, 7(1), 36-50.	This paper investigates the extent to which physics teachers in Vietnam integrate practical work and context-based approaches into their teaching, and explores the how, what, and why they do it.	Survey of 20 Vietnamese high school Physics teachers from 7 schools (100% response rate). Questionnaire about if and how everyday physics phenomena are included in practical work.	Vietnam	High school students	The findings indicate that the Vietnamese teachers value the benefits of both practical work and contextual approaches to teaching and learning physics, but the environment that they are in does not provide sufficient opportunities to implement these methods of teaching.	Recommend inclusion: contains insights about how Vietnamese teachers view practical science.		http://files.eric.ed.gov/fulltext/EJ847202.pdf
Nivalainen, V., Asikainen, M. A., & Hirvonen, P. E. (2013). Preservice teachers' objectives and their experience of practical work. Physics Education Research, 9(1), 1-17.	To explore third-year preservice physics teachers' (n=32) views and experiences concerning the objectives of practical work at school and university.	Content analysis of 32 teachers' essays about practical work	Finland	Pre-service teachers surveyed	1) The objectives of practical work most commonly referred to were related to the connections between theory and practice, motivation, understanding phenomena, learning how to observe, and learning how to report. 2) Preservice teachers' positive experiences of practical work resulted from the successful implementation of practical work. On the other hand, negative experiences reflected failures or difficulties in implementation.	Recommend inclusion: the study has quite an international approach to investigating the purposes of practical science. It provides quite useful information about the purposes stated in the literature as well as presenting teachers' views of the purposes of practical science. The study would be useful in discussing the overlaps and gaps between the purposes of practical science suggested by the researchers (and/or curriculum developers) and those presented by the teachers.	Sample size is quite small and many of the teachers are mathematics teachers (19 out of 32) Pre-service teachers opinions were investigated so it feels like study is more about pre-service teachers' experiences from their studentship rather than their experience as a teacher.	http://journals.aps.org/prstper/pdf/10.1103/PhysRevSTPER.9.010102
Palmer, D. H. (2009). Students' interest generated during an inquiry skills lesson. Journal of Research in Science Teaching, 46(2), 147-165.	The purpose of this project was to investigate situational interest and its sources in inquiry based lessons such as practical work	Post-intervention data collection through the use of questionnaire which generated both qualitative and quantitative responses.	Australia	14 and 15	The results indicated that interest arousal was substantial but did fluctuate throughout the lesson, according to the types of activities in which students were involved. The main source of interest was novelty, although choice, physical activity, and social involvement were also implicated.	Recommend inclusion		http://onlinelibrary.wiley.com/doi/10.1002/tea.20263/abstract

Pine, J., Aschbacher, P., Roth, E., Jones, M., McPhee, C., Martin, C., Phelps, S., Kyle, T. and Foley, B. (2006), Fifth graders' science inquiry abilities: A comparative study of students in hands-on and textbook curricula. J. Res. Sci. Teach., 43: 467–484.	The study compared students in hands-on and textbook curricula	Pre-test post-test design / a sample of about 1000 fifth grade students. Compared the performance of students in hands-on curricula (one of three: FOSS, Insights and STC) with an equal number of students with textbook curricula. The students were from 41 classrooms in nine school districts. Paper and pen tests as well as performance assessments were used.	USA	10 to 11	The results show little or no curricular effect. There was a strong dependence on students' cognitive ability, as measured with a standard multiple-choice instrument. There was no significant difference between boys and girls.	Recommend inclusion (though borderline age)	High quality study with matched experimental and control groups, large-scale, two outcome measures (one derived from TIMSS, one a researcher-developed measure of practical performance). It is not completely clear whether the lack of difference on the performance assessments was a consequence of the assessments, the curricula, and/or the teaching.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20140/abstract
Ritchie, S. M. and Rigano, D. L. (1996), Laboratory apprenticeship through a student research project. J. Res. Sci. Teach., 33: 799–815.	The viability of cognitive apprenticeship for learning science in school is discussed in relation to findings from an investigation of a research project involving high school students working in a university chemical engineering laboratory under the mentorship of a university-based scientist.	Case studies of 2 school students conducting a university-supervised research project. Data from a variety of sources were analysed in an interpretive style.	Australia	14 to 18	Found that the students were empowered to seek empirically viable knowledge claims as they became independent researchers. However, caution needs to be exercised before advocating open-ended inquiry as a general model for laboratory learning without additional studies in different contexts.	Recommend inclusion	Two students only	http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1098-2736(199609)33:7%3C799::AID-TEA6%3E3.0.CO;2-I/abstract
Shim, K.C.; Moon, S.H.; Kil, J.H. and Kim, K (2014). 'Secondary Science Teachers' Views about Purposes of Practical Works in School Science'. International Journal of Social, Education, Economics and Management Engineering, 8(7), pp. 2131-2134.	To "examine views of secondary school science teachers about purposes to use practical works in school science".	Survey of 152 secondary school science teachers (male 70 and female 82; middle school 50 and high school 102), teaching in 42 schools of 8 provinces	South Korea	Teachers surveyed from secondary schools	Teachers surveyed were mostly positive about using practical works to improve skills of scientific inquiry in students. However, they did not use practical-based teaching to improve student capacities to hypothesise or perceive problems. Practical science was also generally associated with "concept confirmation" rather than "concept comprehension".	Recommend inclusion: the study provides additional data on teacher views of practical science	Observations on the purposes of practical science: "main aims of school science instruction are to help students acquire scientific concepts, improve scientific inquiry process skills and science-related attitudes, and actively engage in the process of acquiring scientific knowledge. The practical work has been very emphasized in teaching and learning of science at the school level, because it would be effective to develop students' scientific knowledge that should be seen, and a role as means of communication and opportunities of inquiry [5]-[11]. In addition, curiosity and interest in science, science-related attitude, and nature of science could be improved through practical work" (p. 2131)	http://waset.org/Publications/secondary-science-teachers-views-about-purposes-of-practical-works-in-school-science/9998785
Swain, J., Monk, M., & Johnson, S. (1999). A comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK. International Journal of Science Education, 21(12), 1311-1323.	This paper reports a comparative study of attitudes to the aims of practical work given by science teachers from Egypt, Korea and the UK.	This study reveals a number of huge challenges in science, maths and ICT education in Sub-Saharan Africa: poorly-resourced schools; large classes; a curriculum hardly relevant to the daily lives of students; a lack of qualified teachers; and inadequate teacher education programs. The Educational for All policy has resulted in a growing and heterogeneous student population at the secondary level, creating problems of mixed ability teaching. Textbooks are often available in only limited supply; the same holds true for equipment and consumables for practical work. The policy emphasis is on learner-centered education, but many studies reveal that actual classroom practices are still largely dominated by teachers, with students silently copying notes from the blackboard.	UK, Korea, Egypt	Teachers	The UK teachers have attitudes to aims for practical that reflect current concerns in the UK for investigations. The Korean teachers show a positivistic attitude to science and aims for practical which can be traced back to the emphasis on factual recall and illustrative practicals. The Egyptian teachers show concerns in their choice of aims for practical work which can be traced back to the lack of practical work in current Egyptian science education.	Recommend inclusion	Teacher attitudes to science practical work: limited cross-cultural study.	http://www.tandfonline.com/doi/abs/10.1080/095006999290093#.VVr5cu_blaI
Swain, J., Monk, M., & Johnson, S. (2000). Developments in science teachers' attitudes to aims for practical work: continuity and change. Teacher Development: An international journal of teachers' professional development, 4(2), 281-292.	This study looks at attitudes to the aims of practical work of science teachers in England, and makes a comparison between surveys in 1979 and 1997.	The sample was drawn from science teachers in the South East of England that worked with King's College London on initial teacher training. This sample was part of a wider international comparison that involved science teachers in Korea and Egypt, as well as the United Kingdom. The teachers were invited to rate each of the items from the Beatty & Woolnough instrument on a 4-point scale from very important (1) to unimportant (4). (A 4-point scale was used in the international comparisons.) Then correlations between attitudinal changes were calculated and interpreted.	UK	Teachers	The correlation between attitudinal ratings is remarkably high and indicates minor changes between the two dates. Further extrapolation back to 1962 and an earlier study carried out by Kerr, leads to the tentative conclusion that science teachers' aims for practical work have not changed that much over the past 35 years.	Recommend inclusion	Longitudinal perspective on teacher attitudes to practical work.	http://www.tandfonline.com/doi/abs/10.1080/13664530000200114#.VVr5u-_blaI
Swarat, S., Ortony, A. and Revelle, W. (2012), Activity matters: Understanding student interest in school science. J. Res. Sci. Teach., 49: 515–537	This study investigated the effects of learning environment elements (content topic, activity, and learning goal) on student interest in science.	Using instructional episodes as the unit of analysis, questionnaires and interviews prepared by the researchers were used.	USA	11 to 18	The findings indicated that when judging the interest of an instructional episode, students focused primarily on the form of activity rather than content topic and learning goal. Activities that were "hands-on" in nature and allowed for engagement with technology elicited higher interest.	Exclusion: activities used in the study do not fit in the definition of practical work used in the review		http://onlinelibrary.wiley.com/doi/10.1002/tea.21010/abstract
Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes, and behaviors in high school biology. Journal of Research in Science Teaching, 44(7), 960-979.	To compare traditional teaching approaches to practical work activities in active learning labs in terms of their effectiveness at improving achievement, attitudes, behaviours in high school	6 schools, 6 teachers, 408 students. 2 topics - either use travelling lab or traditional approach (materials available via school for normal classroom instruction). Crossover design. Mixed method approach with post-intervention data collection - observations, interviews, surveys and test of students. Test items drawn from published materials + some original. But designed to reflect content regardless of mode of delivery.	USA	14 to 18	Data show that students gained significantly more content knowledge and knowledge of process skills using the labs compared to traditional instruction. Questionnaire data revealed that students perceived greater learning gains after completing the labs compared to covering the same content through traditional methods. Teaching also seemed to become more student-centred with active learning labs. Little evidence that they supported students' critical thinking skill development.	Recommend inclusion	Several limitations: level of implementation fidelity and topic coverage not clear; reliability and validity of in-class test not fully established; teachers were a small sample of volunteers and may have been biased towards lab condition.	http://onlinelibrary.wiley.com/doi/10.1002/tea.20183/abstract

Varelas, M., Pieper, L., Arsenault, A., Pappas, C. C. and Keblawe-Shamah, N. (2014), How science texts and hands-on explorations facilitate meaning making: Learning from Latina/o third graders. J. Res. Sci. Teach., 51: 1246–1274.	In this study, opportunities were examined for reasoning and meaning making that read-alouds of children's literature science information books and related hands-on explorations offered to young Latina/o students in an urban public school.	Using a qualitative, interpretative framework	USA	5 to 8	The study findings highlight the synergistic relationship between informational texts and hands-on explorations and point to the significance and usefulness of incorporating both in science instruction so that the richness of children's learning experiences are maximized by offering them multiple access points and pathways via the assets they bring to the classroom and the ones they co-construct with their teacher and peers.	Recommend exclusion: below age range, activities used in the study fall outside definition of practical work		http://onlinelibrary.wiley.com/doi/10.1002/tea.21173/abstract
Watson, R., Prieto, T. and Dillon, J. S. (1995), The effect of practical work on students' understanding of combustion. J. Res. Sci. Teach., 32: 487–502.	To investigate 14 and 15 year old students' understanding of combustion in both England and Spain, and explore the effect of practical laboratory experience on students' understanding.	Sample was about 150 students in England and Spain. The teaching and learning styles used with the students in the study were explored using questionnaires and interviews.	England and Spain	14 and 15	The responses of English and Spanish students are significantly different. The quality of the responses is explored in terms of the awareness of students of the involvement of gases in combustion, and it appears, however, that the more extensive use of practical work in English schools has had only a marginal effect on their understanding of combustion	Recommend inclusion	Very specific to understanding of combustion.	http://onlinelibrary.wiley.com/doi/10.1002/tea.3660320506/abstract
Zacharia, Z. C., Olympiou, G. and Papaevripidou, M. (2008), Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. J. Res. Sci. Teach., 45: 1021–1035.	This study aimed to investigate the comparative value of experimenting with physical manipulatives (PM) in a sequential combination with virtual manipulatives (VM), with the use of PM preceding the use of VM, and of experimenting with PM alone, with respect to changes in students' conceptual understanding in the domain of heat and temperature.	A pre–post-comparison study design was used which involved 62 undergraduate students that attended an introductory course in physics. The participants were randomly assigned to one experimental and one control group. Both groups used the same inquiry-oriented curriculum materials. Participants in the control group used PM to conduct the experiments, whereas participants in the experimental group used first PM and then VM. VM differed from PM in that it could provide the possibility of faster manipulation, but it retained any other features and interactions of the study's subject domain identical to the PM condition.	Cyprus	undergrads	Results indicated that experimenting with the combination of PM and VM enhanced students' conceptual understanding more than experimenting with PM alone. The use of VM was identified as the cause of this differentiation.	Recommend exclusion: not school age		http://onlinelibrary.wiley.com/doi/10.1002/tea.20260/abstract

Reviews

Article	Review aims	Key definitions	Inclusion criteria (eg age, date, methods, countries)	Sources searched	Studies included/studies reviewed	Key findings	Incl/excl & why	Other comments	URLs
Cheung, A.; Slavin, R. E.; Lake, C. & Kim, E. (2015) Effective Secondary Science Approaches: A Best-Evidence Synthesis	To conduct a systematic review of research on science programs in grades 6-12		Use of randomized or matched assignment to conditions, measures that assess content emphasized equally in experimental and control groups, and a duration of at least 12 weeks	International Journal of Science Education, Science Education, Journal of Research in Science Teaching, Review of Educational Research, American Educational Research Journal, British Journal of Educational Psychology, Journal of Educational Research, Journal of Educational Psychology, and Learning and Instruction	21 studies	Science educators agree on the importance of inquiry in science education at all levels, and all science curricula include experiments to a greater or lesser degree. Neither inquiry nor experiments are matters of serious debate, though different educators and researchers do have different definitions of inquiry and different ideas of how it should be enacted in practice (Minner et al., 2010; Furtak et al., 2012; Schroeder et al., 2007). However, within this general consensus there remain essential questions about how to improve science achievement.	Recommend inclusion: The review does not deal with practical work as its main focus, but provides insights into practical work that are relevant for the report		http://www.bestevidence.org/science/secondary/sec_science.html
Dillon, J. (2008). A review of the research on practical work in school science. London: King's College.	To create a focused review of research regarding the state of practical work in school science.		Material was selected that appeared in international peer reviewed journals (for example, Science Education, Journal of Research in Science Teaching and the International Journal of Science Education) and professional journals such as School Science Review. Although account was taken of the number of participants, studies in peer-reviewed journals were not excluded or included simply as a result of the 'sample' size.	1) Google scholar 2) The most recent review (Lunetta et al., 2007) of the literature on practical work in school science was identified and read. An electronic copy of the review was obtained from the lead author and this was used to search for new references not revealed by the original search 3) Searches were made of relevant websites (Ofsted, Royal Society, etc.) for documents, press releases, etc. 4) Recent and relevant books on practical work were identified and skimmed (for example, Abrams et al. (2008)).		More practical work does not necessarily mean better. Advocates of more practical work in school science need to be clear about why they take this position and what types of activity they want to see happening.	Recommend inclusion: This review encompasses both quantitative and qualitative evidence on research regarding effective practical work in school science. It is quite comprehensive and broad.	The review is very broad and does not specify a certain focus on certain practical work examples or purposes of practical work which makes interpretation of its results very hard.	http://www.score-education.com/downloads/practical_work/Review_of_Research.pdf
Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. Review of Educational Research, 82, 300-329. doi: 10.3102/0034654312457206	This meta-analysis introduces a framework for inquiry-based teaching that distinguishes between cognitive features of the activity and degree of guidance given to students.		1996-2006, a decade during which inquiry was the main focus of science education reform. Experimental and quasi-experimental. K-12. published in English; those that had a pre-post, two-group design; and those that used a cognitive outcome measure with data provided to calculate an effect size.	Searches were conducted of databases and search engines using a total of 123 search terms to capture studies	1625 studies identified. Reduced to 37 studies from 22 papers.	First, this synthesis of a historical sample of studies from the years in which inquiry-based teaching was returning to prominence indicates a positive effect of this teaching approach on student learning, with a particularly large effect of students engaging in the epistemic domain of inquiry and the procedural, epistemic, and social domains combined. Second, the meta-analysis also indicates higher effect sizes for studies that involved teacher-led activities. Third, and extending beyond the domain of inquiry-based teaching, this meta-analysis has illustrated how a refined model for an instructional approach can yield more nuanced interpretations of the effects of that approach on student learning.	Recommend exclusion: Good overview of the impact of different methods of teaching on students, but insufficient material on practical work.	Useful definition of inquiry based teaching: includes students drawing upon their scientific knowledge to ask scientifically oriented questions, collect and analyse evidence from scientific investigations, develop explanations of scientific phenomena, and communicate those explanations with their teacher and peers	http://rer.sagepub.com/content/82/3/300.abstract
Grajkowski, W., Ostrowska, B., & Poziomek, U. (2014). Core Curriculum for Science Subjects in Selected Countries. Warsaw: Educational Research Institute.	The aim of the analysis was to examine whether the issue of formation and development of the skills of scientific reasoning and using the scientific method plays a similar role and is assigned just as high importance in the Polish Core Curriculum at a specific educational stage binding in 2010 in Poland and in the European countries selected for the study. The purpose of the review was to analyse a selection of European science curricula for content.	Practical science is learning about process and phenomena through practical actions – observation, experiments and measurements.	The selection criterion was determined by the students' results in Science at the international PISA survey in 2006. The selected countries with high average results and average results similar to the Polish ones.	Science Curricula	Poland, England, Czech Republic, Estonia, Finland, France	The analysed foreign core curricula for science subjects contain many elements that refer to development of competences related to scientific reasoning and using the scientific method, which are missing or represented to a limited degree in the Polish document. This includes problem-based approach to teaching content (England, Estonia, Finland), rather than studying separate topics resulting from the 19th-century arrangement of natural sciences (cytology, histology, botany, zoology, etc.).	Recommend inclusion: This review offers good insights into the Polish curricula and into policy approaches to practical sciences.		http://eduentuzjasci.pl/images/stories/publikacje/ibe-report-core-curriculum-for-science.pdf
Hodson, D. (1993). Re-thinking old ways: towards a more critical approach to practical work in school science. Studies in Science Education(22), 85-142.	Examine what practical work achieves for students (sections on motivation, skill acquisition, scientific attitudes etc)		Not systematic			Need more effective teaching in the lab - teaching goals need to be considered. Three areas: learning science, learning about science, doing science. Can achieve some of first two in practical work, but assessment of practical work should focus on doing science well.	Recommend inclusion: A dated review but is the basis for much recent theory on science education.		http://www.tandfonline.com/doi/abs/10.1080/03057269308560022#.VRhbrfnF9i8
Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. Science Education, 88, 28-54.	The study examines scholarship that has emerged in the past 20 years in the context of earlier scholarship, contemporary goals for science learning, current models of how students construct knowledge, and information about how teachers and students engage in science laboratory activities.		Not systematic			There are continuing limitations in systematic scholarship associated with such a central medium as the laboratory in science education. There is new information about limitations in the effectiveness of school science education; there also continue to be important reasons to believe that practical work has special potential as a medium for learning and affects students' perceptions and behaviours in the science laboratory.	Recommend inclusion: this review is authored by two experts who have been frequently cited in research on practical work. It has a good comparison of how practical work is assessed and applied today and how it was 20 years ago.		http://onlinelibrary.wiley.com/doi/10.1002/sce.10106/abstract
Jokiranta, K. (2014) The Effectiveness of Practical Work in Science Education. University of Jyväskylä.	This work is an overview of the modern studies conducted during the last few decades on the subject of efficiency of practical work in promoting the students' conceptual knowledge and understanding of physics.	Undergrad thesis - literature review. Very limited and no evidence of systematic methods.	Finland		Quality of practical work needs to be higher to justify time and resources.		Recommend Exclusion: insufficiently rigorous methods		https://jyx.jyu.fi/dspace/bitstream/handle/123456789/42979/URN%3ANBN%3Afi%3Ajyu-201402181251.pdf?sequence=1
Kieu, T., & Chau, H. N. (2000). Education in Vietnam. Journal of Southeast Asian Education, 1(1), 219-241.	An overview of the education system in Vietnam			Education curricula and policy documents			Recommend exclusion: Use as background for the Vietnam case study, but not specific to practical science		http://seameo-journal.com/journal/index.php/education/article/viewFile/109
Lewin, K. M. (2000). Mapping Science Education Policy in Developing Countries. Secondary Education Series. Washington D.C.: World Bank, Education Advisory Service	To map out the factors that shape science policy in developing countries.		Not systematic. Developing countries			"Most developing country national plans since the 1960s have contained commitments to invest in science and technology in the belief that this will enhance economic development." " Orthodox views of science education tend to stress the importance of discovery, invention and understandings of the natural world over application, improvement of already existing technologies, and the development of scientific knowledge related to the needs of the poor and marginalised. Role models are those of the great scientists who have shaped modern science. Much school science replicates their experiments. The central point is that the kinds of science education and training that might prepare young people to generate new technologies, invent new products, and discover fundamental scientific truths may well not be the same as that best suited to needs to adapt the application of science and technology to new contexts. A strategy to promote technology transfer may invite emphasis on a secure understanding of basic concepts and their application, systematic approaches to the incremental improvement of mature technologies, and the development of diagnostic and maintenance skills, rather than on those of curiosity driven creative exploration" (p. 1)	Recommend inclusion: This paper evaluates the key differences in the purposes of practical science teaching between the developed and developing worlds		http://files.eric.ed.gov/fulltext/ED455104.pdf
Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Teaching and learning in the school science Handbook of Research on Science Education (pp. 393-431). Mahwah: Lawrence Erlbaum Associates.	A review of teaching approaches and methods		Not systematic. Various countries (esp US/UK)			Simplistic solutions are insufficient for improving the impact of practical science. Interventions need to be launched at the teacher training level, as well as the policy level, and in terms of curriculum development	Recommend inclusion		https://books.google.co.uk/books?hl=en&lr=&id=leyrAgAAQBAJ&oi=fnd&pg=PA393&dq=Lunetta,+V.+Hofstein,+A.+%26+Clough,+M.+P.+(2007).+Teaching+and+learning+in+the+school+science.+In+S.+Abell,+%26+N.+G.+Lederman,+Handbook+of+Research+on+Science+Education&ots=mmL-DCxpKN&sig=kDtighwRYxneYdZ-dPY9-N4PeP8#v=onepage&q&f=false
Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. Journal of Research in Science Teaching, 47(4), 474-496.	The goal of the Inquiry Synthesis Project was to synthesize findings from research conducted between 1984 and 2002 to address the research question, What is the impact of inquiry science instruction on K–12 student outcomes?		To synthesise findings from research completed between 1984 and 2002, conducted with K–12 students, having at least one student instructional intervention in science, and having assessed student outcomes. For the purposes of this study, an instructional intervention is defined as a science activity conducted, administered, or initiated by a teacher (or researcher or other instructor) for, to, or with students in a K–12 setting. Additionally: must look at effect of instructional intervention on student outcomes and describe that intervention in sufficient detail to code it adequately.	To generate the data set of studies, exhaustive electronic searches were conducted of databases and search engines using a total of 123 search terms to capture studies that fell under the general description of inquiry-based science instruction. Additionally, a call for research was posted in a variety of publications and reference lists of retrieved documents were searched.	Of the 1,027 documents obtained, 443 research reports met the general inclusion criteria.138 studies met the additional criteria and were analysed	Teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques, which are often necessary in the current standardised-assessment laden educational environment	Recommend Inclusion		http://onlinelibrary.wiley.com/doi/10.1002/tea.20347/abstract
Osborne, J. (1998). Science education without a laboratory? In J. J. Wellington, Practical work in school science. Which way now? (pp. 156-173). London: Routledge.	Review of sources and curricula		Not systematic.			This article argues that reading, writing and argument are central to any conception of science as it is currently constituted. Moreover, it is through the texts of science, popular accounts or journalistic reported versions that the majority of the public interact with and consider the implications of the findings that science presents. However, the study of the language of science, science's epistemic base and the cultural norms and values that underpin its practice are currently considered only marginal to the teaching of science. Rather, the specialised laboratories provided for science teachers and the narrow conception of science embodied in the curriculum gives pre-eminence to science as an empirical activity in the naive belief that this is central to understanding the nature of science. The consequent failure to recognise the centrality of language, literacy and argument to science education leaves the majority ill equipped to become critical consumers of science. Change requires a concerted attempt to reconceptualise the priorities for science education through a mix of new curricula, new strategies and last, but not least, new modes of assessment.	Recommend inclusion in development section		http://www.tandfonline.com/doi/abs/10.1080/03057640220147559#.VRhonPnF9i8
Ottevanger, W., Akker, J. V., & Feiter, L. D. (2007). Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa. Washington DC: World Bank.	To review science education in sub Saharan Africa and develop recommendations for improvement		Not systematic. Multiple Sub-Saharan African locations	Review of sources, grey literature, policy documents and curricula		This study reveals a number of huge challenges in Science, Maths and ICT education in Sub-Saharan Africa: poorly-resourced schools; large classes; a curriculum hardly relevant to the daily lives of students; a lack of qualified teachers; and inadequate teacher education programs. The Educational for All policy has resulted in a growing and heterogeneous student population at the secondary level, creating problems of mixed ability teaching. Textbooks are often available in only limited supply; the same holds true for equipment and consumables for practical work. The policy emphasis is on learner-centered education, but many studies reveal that actual classroom practices are still largely dominated by teachers, with students silently copying notes from the blackboard.	Recommend inclusion in development section		https://books.google.co.uk/books?hl=en&lr=&id=n-vpDU_BIVQC&oi=fnd&pg=PR3&dq=(2007).+Developing+Science,+Mathematics,+and+ICT+Education+in+Sub-Saharan+Africa&ots=7wOrrT9PjJ&sig=yr_dZavk5aWQCsLN1mZQ5LSlU0w#v=onepage&q=(2007).%20Developing%20Science%2C%20Mathematics%2C%20and%20ICT%20Education%20in%20Sub-Saharan%20Africa&f=false
Psillos, D., & Niedderer, H. (2002). Teaching and Learning in the Science Laboratory. New York: Kluwer Academic Publishers.	To review the role of labwork in secondary education		Not systematic.		An edited collection of studies containing illustrations of teaching approaches and of students' learning acquisitions in the science teaching laboratory, presentation of new evaluation tools, theoretical frames and positions concerning laboratory work. One of the characteristic features of the book is that it focuses the discussion on the role of labwork in upper secondary and in higher education, whereas most research and discussion world-wide focuses on labwork in primary and lower secondary education.	A solid summary of existing research, including independent research	Recommend Inclusion		http://site.ebrary.com/lib/york/reader.action?docID=10067328
Schroeder , C., Scott, T., Tolson , H., Huang , T., & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. Journal of Research in Science Teaching, 44(10), 1436-1460.	This project consisted of a meta-analysis of U.S. research published from 1980 to 2004 on the effect of specific science teaching strategies on student achievement. To conduct a systematic review of research on the achievement outcomes of all types of approaches to teaching science in elementary schools		To conduct a systematic review of research on the achievement outcomes of all types of approaches to teaching science in elementary schools		61 studies	The following eight categories of teaching strategies were revealed during analysis of the studies (effect sizes in parentheses): Questioning Strategies (0.74); Manipulation Strategies (0.57); Enhanced Material Strategies (0.29); Assessment Strategies (0.51); Inquiry Strategies (0.65); Enhanced Context Strategies (1.48); Instructional Technology (IT) Strategies (0.48); and Collaborative Learning Strategies (0.95). All these effect sizes were judged to be significant. Regression analysis revealed that internal validity was influenced by Publication Type, Type of Study, and Test Type.	Recommend Exclusion: Minimal focus on practical work, and focused on elementary schools		http://onlinelibrary.wiley.com/doi/10.1002/tea.20212/abstract

Slavin, R. E.: Lake, C; Hanley, P. & Thurston, A. Experimental Evaluations of Elementary Science Programs: A Best-Evidence Synthesis. Journal of Research on Science Teaching, 51(7), 870-901	To conduct a systematic review of research on the achievement outcomes of all types of approaches to teaching science in elementary schools.	The content of science standards is constantly evolving, and is fiercely contested	Study inclusion criteria included use of randomized or matched control groups, a study duration of at least 4 weeks, and use of achievement measures independent of the experimental treatment. Age K-5 (plus Grade 6 if in elementary school). 1980-2012	Electronic databases: ERIC, Psych INFO, Dissertation Abstracts. Hand search of contents: International Journal of Science Education, Science Education, Journal of Research in Science Teaching, Review of Educational Research, Elementary School Journal, American Educational Research Journal, British Journal of Educational Psychology, Journal of Educational Research, Journal of Educational Psychology, and Learning and Instruction.	23 academic papers	A total of 23 studies met these criteria. Among studies evaluating inquiry based teaching approaches, programs that used science kits did not show positive outcomes on science achievement measures (weighted ES 0.02 in 7 studies), but inquiry-based programs that emphasized professional development but not kits did show positive outcomes (weighted ES 0.36 in 10 studies). Technological approaches integrating video and computer resources with teaching and cooperative learning showed positive outcomes in a few small, matched studies (ES 0.42 in 6 studies).The review concludes that science teaching methods focused on enhancing teachers' classroom instruction throughout the year, such as cooperative learning and science-reading integration, as well as approaches that give teachers technology tools to enhance instruction, have significant potential to improve science learning.	Recommend inclusion: The review places greater emphasis on elementary school, than secondary school, but produces findings and observations that may nonetheless be relevant for inclusion		http://onlinelibrary.wiley.com/doi/10.1002/tea.21139/abstract
Walberg, H. J. (1991). Improving School Science in Advanced and Developing Countries. Review of Educational Research, 69(1), 25-61.	This review criticizes and summarizes case studies, cost-effectiveness estimates, surveys, and experiments conducted in primary and secondary education in low- and moderate-income countries. It further summarizes research syntheses (meta-analyses) and reviews in advanced countries.		Past and current research on science education, particularly that with implications for primary and secondary schools in low- and middle-income countries. Although a chief focus is science as a part of general education in schools, postsecondary education is also discussed, as are specialized science programs for students intending to pursue science-based careers in such fields as research, technology, engineering, and medicine.		Review gives greatest weight to findings revealed by large-scale surveys or statistical syntheses (meta-analyses) of primary studies.	"Taken as a whole, [the review] suggests that science education in developing countries can be made considerably more effective and productive. Concentrating resources on primary and secondary schools, rather than on vocational and higher education, and employing efficient educational methods would increase the availability and quality of science education which, in turn, would seem likely to lead to greater equality of educational opportunity and higher levels of economic growth."	Recommend inclusion		http://rer.sagepub.com/content/61/1/25.short
Walberg, H.J. (1991). 'Improving School Science in Advanced and Developing Countries'. Review of Educational Research 61(1), pp. 25-69.	This article reviews past and current research on science education, particularly that with implications for primary and secondary schools in low- and middle-income countries		Not systematic. The review is divided into five sections: 1. Educational Investment in Developing Countries concerns economic efficiency in education. 2. Science for Adult Life summarizes research on what adults know and what they need to know. 3. Time and Motivation in Science shows the importance of these variables for science learning and continuing study. 4. Science Teaching Reforms describes effective methods of teaching. 5. Science Curriculum Reforms reviews and evaluates some of the major science curriculum ideas since 1960.		Draws on first-hand accounts, case studies, and evaluations of science programs carried out by the World Bank and other international development agencies. Case studies, personal impressions, and critical opinions by observers are discussed to illuminate generalizable findings from wide-scale, multiple-site research.	"...science education in developing countries can be made considerably more effective and productive. Concentrating resources on primary and secondary schools, rather than on vocational and higher education, and employing efficient educational methods would increase the availability and quality of science education which, in turn, would seem likely to lead to greater equality of educational opportunity and higher levels of economic growth."	Recommend inclusion		http://rer.sagepub.com/content/61/1/25.full.pdf+html?hwshib2=authn%3A1426355156%3A20150313%253A142cf109-d512-46b2-9d7b-3b4f8d9cfe77%3A0%3A0%3A0%3AuFMpz6fUusRf%2FJF5n62Agw%3D%3D

Opinion pieces

Article	Statement of purpose	Methodology	Country	Age of stu	Key findings	Incl/excl & why	URLs
Gott, R., & Duggan, S. (2007). A framework for practical work in science and scientific literacy through argumentation. Research in Science & Technological Education, 25(3), 271-291	To forge a link between scientific experimentation in schools and emerging ideas of scientific literacy through argumentation.	Opinion piece paper	England	12 to 16	'Public claims' can be used to forge a link between scientific experimentation in schools and emerging ideas of scientific literacy.	Recommend inclusion: the paper has many useful refs to support the necessity of reflection and interaction required for practical work in school science to be effective to achieve its purpose of improving students' understanding of key concepts	http://dx.doi.org/10.1080/02635140701535000
Hodson, D. (2014). Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods. International Journal of Science Education, 36(15), 2534-2553	This opinion piece paper urges teachers and teacher educators to draw careful distinctions among four basic learning goals	Opinion piece paper	New Zealand	12 to 18	The author urges that careful attention is paid to the selection of teaching/learning methods that recognize key differences in learning goals	Recommend inclusion: the author argues very clearly with appropriate evidence that learning goals should be taken into account in deciding about the teaching approaches including practical work examples	http://www.tandfonline.com/doi/abs/10.1080/09500693.2014.899722#.VRNQd-9yZYc
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. Educational Psychologist, 41(2), 75–86.	An examination of the impact of hands-on, participatory learning	Opinion piece paper			Although unguided or minimally guided instructional approaches are very popular and intuitively appealing, the point is made that these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance. Recent developments in instructional research and instructional design models that support guidance during instruction are briefly described.	Recommend inclusion though use with caution: findings are relevant but lack specificity to practical work in the sciences	http://www.tandfonline.com/doi/pdf/10.1207/s15326985ep4102_1
Millar, R. (2004). The role of practical work in the teaching and learning of science Paper presented at the High school science laboratories: Role and vision, Washington, DC	The purpose of this paper is to explore and discuss the role of practical work in the teaching and learning of science at school level.	Opinion piece paper	England	12 to 18	1. Practical work is an essential component of science teaching and learning, both for the aim of developing students' scientific knowledge and that of developing students' knowledge about science. 2. In thinking about the role of practical work, it is important to bear in mind the significant differences between the research laboratory and the teaching laboratory (or classroom); and between research scientists exploring the boundaries of the known and students trying to come to terms with already accepted knowledge. 3. Practical work which aims to develop students' scientific knowledge is best seen, and judged, as communication rather than as inquiry.	Recommend inclusion	http://informalscience.org/images/research/Robin_Millar_Final_Paper.pdf
Millar, R. (2009). Analysing practical activities to assess and improve effectiveness: The Practical Activity Analysis Inventory (PAAI). York: Centre for Innovation and Research in Science Education, University of York.		Opinion piece paper	England	12 to 16	The author presents and explains an instrument, the Practical Activity Analysis Inventory (PAAI), for analysing practical activities to provide a clear description of their principal features.	Recommend inclusion	http://www.york.ac.uk/depts/educ/research/ResearchPaperSeries/index.htm
Millar, R. (2014). Designing a science curriculum fit for purpose. School Science Review, 95(352), 15-20	Aims to suggest a clear view of the purposes of science education rooted in a view of the purposes of education itself.	Opinion piece paper	England	12 to 18		Recommend inclusion	https://www.ase.org.uk/journals/school-science-review/2014/03/352/
National Research Council (2000). Inquiry and the national science education standards: A guide for teaching and learning. Washington, DC: National Academies Press.	Policy Paper: students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking to expand human knowledge of the natural world. Yet the activities and thinking processes used by scientists are not always familiar to the educator seeking to introduce inquiry into the classroom. By describing inquiry in both science and in classrooms, this volume explores the many facets of inquiry in science education. Through examples and discussion, it shows how students and teachers can use inquiry to learn how to do	Policy paper	USA		We reflect on the world around us by observing, gathering, assembling, and synthesizing information. We develop and use tools to measure and observe as well as to analyse information and create models. We check and re-check what we think will happen and compare results to what we already know. We change our ideas based on what we learn.	Recommend exclusion: Not relevant to case studies	http://www.nap.edu/openbook.php?record_id=9596&page=R5
Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Boston: Houghton-Mifflin.		Theoretical exploration			Some of the terms used in describing modern experimentation (see Table L.L) are unique, clearly defined, and consistently used; others are blurred and inconsistently used. The common attribute in all experiments is control of treatment (though control can take many different forms). So Mosteller (1990, p. 225) writes, "in an experiment the investigator controls the application of the treatment" and Yaremko, Harari, Harrison, and Lynn (1,986, p.72) write, "one or more independent variables are manipulated to observe their effects on one or more dependent variables." However, over time many different experimental subtypes have developed in response to the needs and histories of different sciences (Winston, 1990; 'Winston & Blais, 1996).	Recommend Exclusion: Overly general	https://depts.washington.edu/methods/readings/Shadish.pdf

Wellington, J. (1998). Practical Work in School Science: Which Way Now? London: Routledge.	To look beyond TIMSS data and to ask what is going in laboratory activities and why. To re-appraise the role and purpose of practical science.	Edited book: chapters contributed by various authors	England		Wellington concludes that practical science is a necessary part of the curriculum but there should be no one set format. It should combine hands-on with minds-on (eg analysing third party data sets), use of simulations, IT, controversial issues, and an extended science investigation rather than the artificial, lesson-based ones. Important to link theory and practice. Purposes of practical should be made explicit to students.	Recommend inclusion (Note: Osborne chapter included under Reviews)	https://books.google.co.uk/books?hl=en&lr=&id=2ZqOYcavPrEC&oi=fnd&pg=PR8&dq=practical+work+in+school+science+-+which+way+now&ots=z6nxSclzDM&sig=lEQEvROKNNWy_HDnH3F3yQJ2S04#v=onepage&q=practical%20work%20in%20school%20science%20-%20which%20way%20now&f=false
White, R. T. (1996). The link between the laboratory and learning. International Journal of Science Education, 18(7), 761-774	Paper argues the link between practical work and student learning, discusses the currently available evidence about the effectiveness of practical work	Opinion piece paper	Australia	12 to 18	Despite the cost, laboratories are so embedded in the practice of science teaching it is difficult to imagine doing without them. Yet their purpose is not universally agreed, and evidence of their effect is equivocal.	Recommend inclusion	http://dx.doi.org/10.1080/0950069960180703

March 2017 Additional Review

Post-2014 studies/articles (T=technology; rev=review; O=opinion)	Article	Statement of purpose	Methodology	Country	Age of students	Key findings	Incl/excl & why	URLs
T	Yeh, Y. F., Lin, T. C., Hsu, Y. S., Wu, H. K., & Hwang, F. K. (2015). Science teachers' proficiency levels and patterns of TPACK in a practical context. Journal of Science Education and Technology, 24(1), 78-90.	Explore high school science teachers' level and proficiency in TPACK-P (technological PCK - practical) in the classroom.	Interviews	Taiwan	Secondary school	Three different types of teachers with distinctive features were identified: technology-infusive (TI), technology transitional (TR), and planning and design (PD).	Excl - not about practical work	http://link.springer.com/article/10.1007/s10956-014-9523-7
T	Peffer, M. E., Beckler, M. L., Schunn, C., Renken, M., Revak, A. (2015) Science Classroom Inquiry (SCI) Simulations: A Novel Method to Scaffold Science Learning. PLoS ONE 10(3): e0120638. doi:10.1371/journal.pone.0120638	Not explicit: can simulations support authentic, real-life learning in the classroom?	3 science classroom inquiry (SCI) simulations were designed as website applications to give students (n=88) real life, authentic science experiences within the confines of a typical classroom. For each simulation, students had to solve a scientific problem through investigation and hypothesis testing. Post-survey to explore feedback about difficulty, perceived effectiveness etc.	US	6th-12th grade	67% of students reported a change in how they perceived authentic science practices, specifically related to the complex and dynamic nature of scientific research and how scientists approach problems. Moreover, 80% of the students who did not report a change in how they viewed the practice of science indicated that the simulation confirmed or strengthened their prior understanding. Authors state SCI simulations are a valuable and versatile technology that can be used to educate and inspire a wide range of science students on the real-world complexities inherent in scientific study.	Incl with caution - no comparison group, lead author designed SCI so vested interest.	http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0120638
	Nikula, T. (2015). Hands-on tasks in CLIL science classrooms as sites for subject-specific language use and learning. System, 54, 14-27.	the potential of hands-on tasks in CLIL chemistry and physics lessons to serve as sites for using and learning subject-specific language	Discourse analysis	Finland	13 year olds	Subject-specific language is useful for content and language integrated learning	Excl - very small study, focused on language	http://www.sciencedirect.com/science/article/pii/S0346251X1500055X
T	Sharples, M., Scanlon, E., Ainsworth, S., Anastopoulou, S., Collins, T., Crook, C., ... & O'Malley, C. (2015). Personal inquiry: Orchestrating science investigations within and beyond the classroom. *Journal of the Learning Sciences*, *24*(2), 308-341.	to explore various concerns about introducing a combination of new technology and pedagogy, eg how to best design scripted personal technologies, how teachers can be enabled, how the activities support learning.	Evaluations in the second and third years of the project consisted of intervention studies in schools involving video-recorded observations; interviews with teachers and students; analyses of computer log files; and pre- and post-intervention studies of changes in domain knowledge, knowledge of the inquiry process, and attitudes to science. Intervention (n=28) and control (n=15) group, but not well-matched at baseline.	England	11-14 yrs	Findings from the studies indicate that the toolkit was successfully adopted by teachers and pupils in contexts that included teacher-directed lessons, an after-school club, field trips, and learner-managed homework. It effectively supported the transition between individual, group, and whole-class activities and supported learning across formal and informal settings. Authors discuss issues raised by the intervention studies, including how the combination of technology and pedagogy provided support for the teacher despite difficulties in managing the technology and integrating field data into a classroom lesson. Intervention group significantly improved its accuracy of inquiry over time, and tended to increase its insight scores, but control group didn't - but can't assume only due to intervention. Authors also discuss the difficulty of altering young people's attitudes to science.	Incl	http://www.tandfonline.com/doi/abs/10.1080/10508406.2014.944642
	Yoon, S. A., Koehler-Yom, J., Anderson, E., Lin, J., & Klopfer, E. (2015). Using an adaptive expertise lens to understand the quality of teachers' classroom implementation of computer-supported complex systems curricula in high school science. Research in Science & Technological Education, 33(2), 237-251.	to propose a model of adaptive expertise to better understand teachers' classroom practices	3 case studies	US	high school	using an adaptive expertise model helps professional developers and researchers interested in learning how to train teachers to teach with complex systems resources and approaches by illustrating the range of contextualized classroom enactment	Excl - not about practical work	https://pdfs.semanticscholar.org/69e4/887f5ada63ac1539c04c3b772a17ca8d9d85.pdf
	Martindill, D., & Wilson, E. (2015). Rhetoric or reality? A case study into how, if at all, practical work supports learning in the classroom. *International Journal for Lesson and Learning Studies*, 4(1), 39-55.	to investigate the precise role of practical work in the learning of a specific topic over a series of lessons	case study of two classes: post-test, coursework and focus groups plus pre-perceptions survey, interview and lesson observation. One class had practical work, other didn't, over course of one topic (kidney structure and function)	England	year 9 (13-14)	Practical group outperformed non-practical on test. Practical work supported learning by: visualisation of abstract concepts stimulating later recall of key facts; opportunity to work collaboratively with associated gains; hands-on classroom was motivational.	Incl (though small-scale)	http://search.proquest.com/openview/b4c95939b0e4049e41a3fa6e707e5de2/1.pdf?pq-origsite=gscholar&cbl=1396353
T	Chiu, J. L., DeJaegher, C. J., & Chao, J. (2015). The effects of augmented virtual science laboratories on middle school students' understanding of gas properties. Computers & Education, 85, 59-73.	Can virtual science labs help students develop explanations and refine alternative ideas? Specifically, using the augmented virtual technology Frame that uses probeware (temp and pressure sensors) as inputs to simulations of scientific phenomena, so students use real-world objects to control the simulation. Ie augmented virtual technology is a mix of virtual and physical components.	Four classes worked through 2 x 90 minute class sessions on the Gas Frame. Observations, field notes, trace information about student interaction with the IT. Pre- and post-questions (open-ended) asking for explanations of various gas phenomena - 3 proximal (ie same context as lab) and 3 distal (ie different context though similar concepts). 9 days between pre (day before unit) and post.	US	8th grade from one middle school	Significant pre/post improvement and large effect size. But no comparison group so really just saying they were taught about a topic and now know/understand more about it - no idea if another way of teaching would be more, less or equally effective. Did find students made more progress in some topic aspects than others. Suggests augmented virtual approaches can be useful in real classroom context.	Incl - tho small scale, no control, identical pre/post test 9 days apart, v short topic	http://www.sciencedirect.com/science/article/pii/S0360131515000512
T	Meij, H., Meij, J., & Harmsen, R. (2015). Animated pedagogical agents effects on enhancing student motivation and learning in a science inquiry learning environment. Educational technology research and development, 63(3), 381-403.	Do students' motivation and knowledge change over time as they work in the inquiry learning environment, and does condition and gender affect such changes? Or: can student motivation in a science inquiry learning environment be enhanced with a motivational animated pedagogical agent (APA)? What is the influence of an APA on learning?	3 conditions: control (no image or voice); voice (no image); agent (image and voice). 61 students from 4 classes in one school, randomly assigned but stratified by class and gender. Topic was uniformly accelerated motion. 29 assignments. Knowledge pre-test one week before training; post test apparently soon after training (measured same constructs but text and order differed pre to post). Also used pre/during/post task relevance and self-efficacy measure.	Neths	13-16 years	Although performance improved, this showed no difference by condition or gender. Girls' increased their self-appraisal of confidence more than boys, but it was still significantly lower than for boys. Conclusions about effectiveness of APAs so far is mixed, need more work on how to design agents well.	Excl - about comparing agents in simulations not simulation vs "authentic" practical	http://link.springer.com/article/10.1007/s11423-015-9378-5
T	Minshew, L., & Anderson, J. (2015). Teacher self-efficacy in 1: 1 iPad integration in middle school science and math classrooms. Contemporary Issues in Technology and Teacher Education, 15(3), 334-367.	How barriers on integration of i-pads in classroom affect pedagogy	Focus on 2 middle school teachers (one science). Interviews, lesson obs, lesson plans etc	US	6th grade	Series of internal and external barriers that need to be overcome.	Excl - Focuses on barriers. No detail about practical work.	http://www.citejournal.org/volume-15/issue-3-15/science/teacher-self-efficacy-in-11-ipad-integration-in-middle-school-science-and-math-classrooms/
T	Al Musawi, A., Ambusaidi, A., Al-Balushi, S., & Al-Balushi, K. (2015). Effectiveness of E-Lab Use in Science Teaching at the Omani Schools. TOJET: The Turkish Online Journal of Educational Technology, 14(1).	Study the effectiveness of the e-lab in teaching science on a set of teaching-learning variables such as: academic achievement, science processes, scientific attitudes, attitudes towards the use of e-labtechnology, estimation of the classroom environment, visual thinking, and laboratory skills	Pre/post achievement and practical assessments; experimental and control groups	Oman	4th grade	Not yet reported	Excl - Primary age children; findings not yet reported	http://files.eric.ed.gov/fulltext/EJ1057335.pdf
	Chairam, S., Klahan, N., & Coll, R. K. (2015). Exploring secondary students' understanding of chemical kinetics through inquiry-based learning activities. Eurasia J. Math. Sci. Technol. Educ., 11(5).	to explore students' understanding of chemical kinetics and their science process skills when engaged in the use of inquiry-based learning activities	Students from one school (single class). Worked in groups of 4-5 to complete each expt in a 3-hour lab session (guided practical). Diagnostic test (pre and post); practical diagram and qaire.	Thailand	grade-11 (17-18)	Students made significant progress in drawing the concept lists, phrasing the scientific question, identifying the experiment groups, designing the experiments, presenting the data, analyzing the results, but only modest progress on drawing conclusions in practical classes. Seemed to have a positive effect on their interest and understanding.	Excl - small-scale and no comparison group so pretty meaningless in isolation.	http://scholar.googleusercontent.com/scholar?q=cache:PM9wQ0kIV2AJ:scholar.google.com/+Chairam,+S.,+Klahan,+N.,+%26+Coll,+R.+K.+(2015).+Exploring+secondary+students%E2%80%99+understanding&hl=en&as_sdt=0,5
	Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. Journal of Science Education and Technology, 24(6), 898-909.	How positive are post-treatment science dispositions; how do they compare with other groups?; how do they vary by type of activities or gender	Used STEM semantics survey on 3 groups of students who did different activities (eg after school robotics club). Group size varied from about 80 to over 300.	US	varied by group eg 6-8th grade, 10th - 11th grade	Hands-on activities, active learning etc may be effective in creating or maintaining positive interest in STEM content and careers	Excl - no pre and post, not clear how comparable comparison groups really are; practical science (here=hands-on) mixed up with active learning and other approaches.	http://link.springer.com/article/10.1007/s10956-015-9572-6
T rev	Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, *87*, 218-237.	How do learning outcomes compare for trad vs non-trad lab users? What (a) learning outcomes and (b) assessment tools are used and is there consistency (in outcomes/application) across studies?	Synthesis of post-2005 comparing learning outcomes of trad vs non-trad lab users		K-HE	56 studies met the inclusion criteria: 65% showed learning equal or higher in NTL across all six learning outcome categories (see para below); 24% equal; and 16% higher in TL. Six outcome categories were defined: knowledge and understanding, inquiry skills, practical skills, perception [engagement etc], analytical skills and social and scientific communication – based on the US National Research Council framework. Note that 95% of the studies focused on outcomes related to content knowledge and only 7% (ie 4 studies) on scientific inquiry skills. Degree of difference in achievement between the modes depended on outcome category. For example, studies supporting higher achievement in NTL tended to emphasise content knowledge and understanding (with quantitative tests as assessment), those showing higher achievement in TL tended to rely more on qualitative data and be based on perception.	Incl - useful review	http://www.sciencedirect.com/science/article/pii/S0360131515300087
	Burkett, V. C., & Smith, C. (2016). Simulated vs. Hands-on Laboratory Position Paper. *Electronic Journal of Science Education*, *20*(9).	Are virtual laboratory experiments acceptable substitutes for hands-on laboratories in secondary education?	Opinion piece based on empirical studies.	US	Secondary school	Outlines pros of simulated labs (accessibility; relative cheapness; equally or more effective; time-saving eg not having set up equipment; safer) and cons (not acceptable substitutes for hands-on labs (eg professional bodies); insufficient evidence for equivalence (studies are often of short duration and the simulated labs are an exception for the students); not the best format eg for building teamwork, reproducing the open-ended nature of real lab events [unexpected results etc]). Recommends using laboratory simulations to supplement rather than replace traditional hands-on laboratories.	Incl	http://ejse.southwestern.edu/article/view/16255
	Jobér, A. (2016). Revising laboratory work: sociological perspectives on the science classroom. Cultural Studies of Science Education, 1-21.	How sociological perspectives on pupils doing laboratory work can broaden our understanding about science as a gatekeeper and a creator of equal opportunities	~ ethnographic study of one class of 14-15s in lab work, so mainly obs, questionnaires, interviews. 5-week physics course.	Sweden	14-15	Sociological perspective of lab work which highlights contradictions between its group work and individual nature. Argues that practical work is dominated not by scientific inquiry but by group processes. Though small scale ethnography, raises interesting points about considering social interaction in practical work as it's so often based on small group working.	Incl	http://link.springer.com/article/10.1007/s11422-016-9750-1