Does the new GCSE science curriculum improve the effectiveness of practical work in Key Stage 4 classes?

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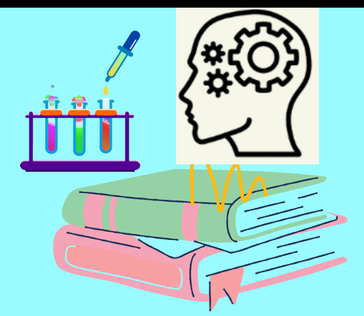
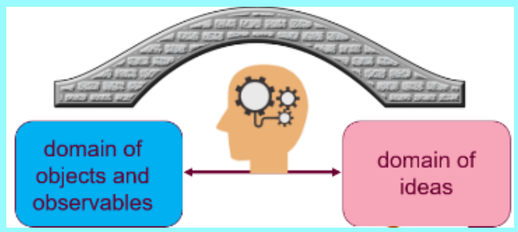
INTRODUCTION

This study evaluates the effectiveness of practical work under the Key Stage 4 science curriculum reformed in September 2016 in England. Previously, practical work, although effective in teaching manipulative skills i.e. in the domain of objects and observables, was seen as ineffective in developing conceptual understanding i.e. in the domain of ideas (Abrahams and Millar, 2008). The 2016 reform shifted from directly awarding 25% of marks for practical lab work to assessing practical understanding through exam questions worth 15% of marks, focusing on required practicals in each science subject. Assessment and curriculum drive school teaching (Cullinane and Liston, 2016; Reiss, Abrahams and Sharpe, 2012).
The curriculum changes necessitate students to thoroughly comprehend the required practical, hence potentially developing the effectiveness of practical work. Students are now expected to retain and recall the information of about 24 GCSE science practical which are studied over the course of 2-3 years. Interest in developing memory has grown, emphasising the integration of new knowledge into long-term memory (Ofsted, 2019) equating learning with changes in long-term memory. The lure of Sweller's (1988) Cognitive Load Theory (CLT) is understandable, as it claims to provide strategies that help students to integrate new knowledge into their long-term memory and to make enduring connections that foster understanding. CLT has become the 'next big thing' in education since Dylan Wiliam's (2016) tweet and forms the research evidence informing the Ofsted (2019) inspection framework. Teaching practice is likely to adapt, considering the limitations of working memory, to develop memory retention and recall. On the other hand, prior to 2016, the incorporation of practical work in schools, despite its expense and time requirements, was validated by its direct assessment in GCSE exams. The 2016 assessment modifications have sparked fears of practical work devaluation (Cramman et al., 2019) and cost-driven reduction in its implementation.



METHODOLOGY

A multiple case study with a single unit of analysis was adopted with a critical realist stance. Data was collected through observations, teacher interviews and student focus group interviews which provided multiple perspectives. This study positioned within an interpretive qualitative approach. Instead of just observing a practical session, data was collected by observing a sequence of lessons involving GCSE required practical in four different schools in England, teacher interviews and focus group interviews with students. This study adapted the 2 x 2 effectiveness matrix (Abrahams and Millar, 2008) by drawing on the Cognitive Load Theory (CLT) (Sweller, 2020), to consider the effectiveness of the required practical.



Analytical framework

LEVEL TYPE	DOMAIN TYPE	OBJECTIVES	STRATEGIES USED TO ENABLE UNDERSTANDING OF THE PRACTICAL
L1: Doing A practical task is effective at this level if students do the task as the teacher intended them to.	**L1Do Objects and Observables** Students use the provided materials and apparatus and generate data in the manner intended by the teacher.	The teacher's intentions are specified in terms of what students will **do** in the practical session, including how they generate data. DfE-mandated **AT skills** mapped to the practical are also deemed an objective.	Strategies planned by the teacher and used *in response* to students to facilitate a complete understanding of what they need to **do** in the practical task.
	L1Di Ideas The students think about the practical method and the observations using the ideas that the teacher intended them to use.	The teacher's intentions are specified in terms of **the ideas and concepts** that underpin what students are doing during the practical	Strategies used by the teacher and *in response* to students to facilitate a **complete understanding of the underpinning ideas and concepts** and their link to the observations and data from the practical work.
L2: Learning A practical task is effective at this level if students learn what the teacher intended them to.	**L2Do Objects and Observables** Students can later recall the practical method, materials, equipment, observations, and key features of the practical and/or the pattern of the collected data.	The teacher's intentions are specified in terms of what **students can recall** about the practical session – **the method, materials and equipment** and how data was generated.	Strategies used by the teacher and *in response* to feedback from students after the practical to ensure students **recall what they did** in the practical task and **how they generated the data.**
	L2Di Ideas Students can later express their understanding of their practical task observations and data using the scientific	The teacher's intentions are specified in terms of what **should be recalled** by students on the **ideas** that underpin the practical.	Strategies used by the teacher and *in response* to feedback from students after the practical **to enable recall of the underpinning ideas and concepts** and their link to the observations and data from the practical work.

ANALYSIS

The data was analysed by adapting the framework used by Abrahams and Millar (2008) to accommodate ideas from cognitive load theory (CLT) (Sweller, 2020). This study views learning from practical work from the extent that students recall the practical and explain their observations and results using the associated ideas after the practical.

Effectiveness in L1Do: Practical work at L1Do was partly effective in L1Do as students did not use the thermometer to note the temperature during the distillation of ink (-AT1, -L1Do.Kobj1). The practical design didn't support the development of all aspects of the SC1 skills (-L1Do.Kobj6). Students were not seen observing the colour change of the ink (-L1Do.Kobj7)

Objectives and AT skills partly or not met

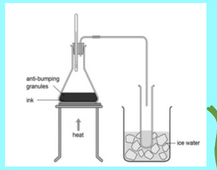
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including […] temperature […].

L1Do.Kobj1: To use the thermometer appropriately.

L1Do.Kobj6: To develop proficiency in SC1 skills.

L1Do.Kobj7: To observe effectively.

Effectiveness of the Distillation of Ink practical within L1Do

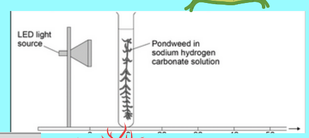


Effectiveness in L2Do: For L2Do, the practical was effective as the students could recollect what the teacher intended them to, as well as the exam board requirement, about the distillation and chromatography practical. They also recalled how to set up the apparatus and all the steps of the task; thus, achieving all the intended objectives.

Objectives and Edexcel requirements partly or not met

None

Effectiveness of the distillation practical within L2Do



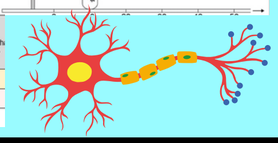
Distance from light (cm)	Number of bubbles per minute (the rate of photosynthesis) 1st	2nd	3rd	Average	Light intensity (LUX) (LUX × 1 ÷ distance²)
10					
20					
30					
40					

Effectiveness in L2Di:
Practical work was effective in Level 2 – Domain of ideas as students explained their results in terms of concentration and by referring to the concept of osmosis. It seems th the time spent and the one-to-one support provided by Ms Chowdhury in the follow-up lessons helped students to understand the collected data.

Objectives partly or not met

None

Effectiveness of the Osmosis practical within L2Di



CONCLUSION

This study concludes that teachers are the driving force, using a range of strategies, for ensuring practical work is carried out as intended. However, there is less emphasis on the development and monitoring of students' apparatus use and techniques outlined in the curriculum. Time constraints in practical sessions necessitate absolute clarity of learning outcomes to maximise the epistemic development opportunities and develop manipulative skills. Awarding bodies must provide much clearer guidance on dealing with student absences from required practical to prevent erosion of 'hands-on' practical work through a lack of further opportunities to experience it.
Practical work was primarily ineffective in developing ideas within the practical lesson due to time constraints. In the post-practical sessions, the effectiveness of the practical work at the learning level improved with retrieval practice, discussion of practical method and results, and use of exam-style questions. However, teachers need to have a clear idea of what they want students to learn from the practical to facilitate opportunities for this. The use of a lab book and exam-style questions can develop the ideas, provided the discussions are with the whole class and they are used periodically in retrieval practice. The increased focus on memorising a large volume of practical methods, especially to answer the '6- marker questions' is causing anxiety for teachers and pupils.

The change in the assessment of practical work seems to have shifted teachers focus from developing manipulative skills used to carry out lab work, to developing an understanding of the results, which means the direction of travel is now towards the 'domain of ideas' – a previously neglected area, as evidenced by Abrahams and Millar (2008).

RESULTS

The effectiveness of the practical work at the 'doing' level

L1Do: Teachers used structured method sheets, demonstrations, verbal instructions and class circulation to ensure students carried out the practical task. High cognitive load (CL) was managed by breaking the practical into small, manageable tasks.Overall, the practical work was effective in getting students to do what the teacher clearly intended during the session but the focus was not much on developing the DfE-mandated Apparatus and techniques (AT). The threat to the de-prioritisation of 'hands-on' work comes from the differing interpretations of the guidance on managing student absences from the required practical. Awarding bodies must provide much clearer guidance on this matter.

L1Di: The study found that practical work in lessons is ineffective in developing ideas due to time constraints. On the rare occasions of discussing and analysing practical observations, not all aspects of the ideas were developed or addressed within the practical lesson. To develop all ideas, clearly defined learning outcomes must be in place for teachers to structure their conversations to ensure epistemic progress.

The effectiveness of the practical work at the 'learning' level

L2Do: The effectiveness of the practical work at the 'learning' level was developed in the post-practical session through retrieval practice, discussion of practical method and results, and use of exam-style questions. Teachers also used flashcards, mnemonics and analogies to help students remember information. Doing the practical enabled students' recall of the procedure and observation. Students struggled to recall steps that were unclear or omitted during the practical. Recall of procedures from previous practicals weakened over time. The difficulty in recall was a cause of anxiety for students, mainly due to the inclusion of questions, including the '6-markers', worth 15% of the GCSE grade in their exam papers.

Practical 6 Mark Questions

L2Di: This study found that time in the post-practical session was spent discussing the practical results and answering questions, mainly from the textbook or the lab books. Teachers focused on developing ideas using exam-practice questions, but this practice must not replace the discussion of results. Discussion of practical results were impeded due to students' weak mathematics skills. The dual provision of one-to-one and whole-class support was the most effective in helping students plot and interpret graphs.

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