No Man is an Island, neither Practical Work is: A Case Study into Undergraduate Life Sciences

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The teaching of undergraduate sciences has long been associated with practical work which has been advocated for promoting theoretical understanding and learning along with the acquisition of practical skills. However, considering the expensive nature of conducting practical work in science departments, its role has been unchallenged concerning the real benefits in supporting undergraduates' learning. This paper reports on findings of a mixed-methods case study conducted at a British university to examine the effectiveness of practical work on conceptual understanding and skill development. Laboratory observations and on-the-spot informal assessment of undergraduates' understanding and skill development provide an objective empirical perspective on how the structuring of practical work lessons can assist in learning. Preliminary findings showed that practical work is effective with regard to skill development while effectiveness concerning conceptual understanding might depend on how the lesson is staged by members of staff.

Keywords: *work in tertiary education; Undergraduate practical work; Practical work in life sciences; Practical work*

1. Introduction

For many years, teaching life sciences has been associated with practical work and learning in the laboratory; a practice that has been unchallenged concerning its effectiveness yet assumed to promote conceptual understanding of scientific theories along with skill development. Whilst the purpose of practical work in sciences has been extensively discussed [1] the teaching aims have changed over time, focusing from solely teaching technical subject-related skills to becoming more diverse and targeting, amongst others, the better visualisation of scientific theory [2]. Almost half a century after the publication of Kerr's ten aims of practical work in secondary education [3], research findings have shown that those exact aims still resonate and can equally apply to tertiary level sciences [4].

Whilst the importance of practical lessons focusing on training and practicing laboratory skills has been adequately reported in the literature [4,5] along with its effectiveness [4], the promotion of conceptual understanding has been questioned due to the absence of such evidence [6,7]. Overall, whilst practical work has been reported to be effective in terms of training undergraduates in developing manipulative skills [4], it would not be reasonable to assume the development of conceptual scientific knowledge as a direct 'side-effect' of the activity *per se*.

The present paper presents preliminary findings of a research study which focused on the effectiveness of practical work in tertiary life sciences and is being guided by two main research questions:

1. Are practical tasks effective in enabling undergraduates do what intended?
2. Are practical tasks effective in enabling undergraduates learn what intended?

2. **Methodology**

An initial aim of this research study was to provide empirical evidence on how undergraduates engage in practical work in the department of life sciences, therefore *in situ* observations in the laboratory setting were vital. It is important to note that effectiveness in this paper is based on what members of staff at the department of life sciences intended their undergraduates to achieve at the end of the practical work lesson observed. Triangulation of data deriving from multiple data sources was used to examine findings from different facets, and a more detailed analysis and summary of findings is to be presented in subsequent publications. An opportunistic sampling method was adopted, recruiting undergraduates from Year 1 (n= 256) and undergraduates from Year 2 (n=211). Undergraduates were observed and interviewed while doing practical work and were informally assessed with respect to what they were doing and what they were thinking while doing their experiments as well as what they could recall from previous practical work lessons (eighteen different practical work lessons were observed in total, nine for each of Year 1 and Year 2). Laboratory protocols were carefully studied beforehand and ,with guidance from members of staff, probing questions about underlying theory related to the experiments and technical procedures were formulated. The Practical Activity Analysis inventory instrument developed by Millar [8] guided the assessment of effectiveness at Level 1 (Did undergraduates do what they were intended to do and see what they were intended to see?) and effectiveness at Level 2 (Did undergraduates learn what they were intended to learn?). The theoretical model guiding this research study is presented in Figure 1 and was used in order to assess effectiveness through the lens of learning outcomes members of staff set for the laboratory lessons delivered concerning learning and doing [9] along with two domains [10] which are distinguished between these activities related with ‘ideas’ and ‘observables’.

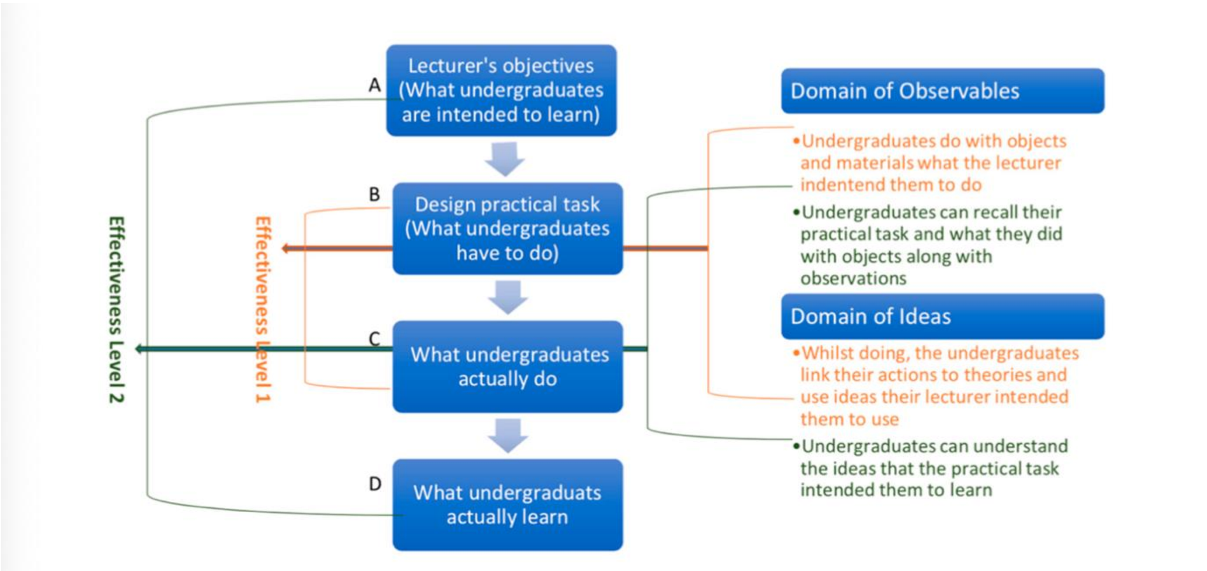

Fig 1. Theoretical model for the effectiveness of practical work [9,10]

3. Findings

Skill development.

The majority of practical work lessons focused on skill development [4] with undergraduates learning how to use laboratory equipment, execute tasks on a protocol, and develop understanding of the scientific approach to enquiry, something which was in line with the top 3 aims set for practical work lessons in Year 1 and Year 2, previously published [4]. Findings indicate that practical work is effective in the domain of observables at Level 1. The majority of undergraduates demonstrated abilities in using equipment in a correct way, follow procedures to carry away the experiment correctly and follow instructions given so as to carry experiments and generate data, the way members of staff intended them to, after being explicitly guided. In all but one Year 1 practical work lessons and in 7 out of 9 Year 2 lessons, undergraduates were mainly engaged in expository activities, therefore members of staff were given teaching space to provide guidance. However, undergraduates could not observe the outcomes or effects members of staff wanted them to see, without assistance. Furthermore, findings from this study showed that skill training, prioritised for preparing undergraduates for their future careers, was treated separately from data collection as skills were developed with repetition and staff supervision regardless of whether undergraduates could acquire intended data, indicating that the development of skills happens gradually and can co-exist with other learning goals simultaneously without having their value compromised.

Conceptual Understanding

Even though all practical work lessons observed were linked to specific scientific theories and concepts, the importance of scientific ideas to carry out the activity well for both Year 1 and Year 2 was not very important neither was the development of scientific knowledge, **in the laboratory while doing practical work,** as it was not regarded as part of the departmental aims of conducting practical work [4]. Explaining the activity verbally helped undergraduates understand the rationale behind their experiment and this is reflected in the fact that in 17 out of 18 lessons observed, undergraduates could explain what the activity was for and why they were doing it. However, there is less evidence that undergraduates could think about their observations using underlying ideas, on their own. Thinking about observables within a theoretical framework is challenging as the connection is sometimes indirect to what undergraduates are seeing albeit actively participating [11].This study has been unable to demonstrate that practical work as an activity on its own can aid in the better understanding of science theories as undergraduates cannot think about the scientific theory without scaffolding, at least not in Year 1 and Year 2 when undergraduates are still training in acquiring skills, thinking scientifically, problem solving and carefully observing and recording [4]. An adequate understanding of ideas from the majority of undergraduates in the laboratory (50-88%) which fell within levels where answers were considered correct and aligned with members of staff learning goals, was only observed in 4 out of 18 practical work lessons for both Year 1 and Year 2.

Discussion

Careful comparison of the structural characteristics of practical work lessons during observations gave insights on patterns that proved to be beneficial in promoting better conceptual development and recalling of observations in the laboratory. Findings showed that laboratory lessons where conceptual understanding and recalling was demonstrated by 50-88% and 50-75% of undergraduates, respectively, were structured in such a way that verbal discussion on the experiment's purpose and its underpinning scientific ideas were provided at the beginning of the lesson and confirmation of observations at the end, something that might have contributed in successful subsequent recalling of information.Moreover, even though a practical work lessons for the majority of core modules usually consisted of approximately 100 undergraduates, the aforementioned 4 out of 18 practical work lessons showing evidence of successful understanding and recalling of ideas, consisted of 40-52 undergraduates in total.

Interestingly, successful recalling might be attributed to, as undergraduates explained, engagement in laboratory discussions as well as complementary out-of-laboratory learning opportunities (lectures, self-studying) that aid in reflecting on the practical work experience therefore gaining deeper understanding. Preliminary findings show that practical work was effective as the outcome was in line with what members of staff intended undergraduates to achieve; developing manipulative skills and promoting simple scientific methods of thought. Overall, undergraduates did not have a better understanding of underpinning scientific ideas related to their experiments, but this was not expected from them anyway. Undergraduates had the opportunity and were in fact capable in linking the domain of ideas with the domain of observables in practical work lessons where class size was manageable, through effective in-class discussion, scaffolding and probing from members of staff.

This paper suggests that practical work in the laboratory serves as a teaching medium and does not directly promote theoretical understanding of sciences as a stand-alone practice. Practical work should be regarded as an activity which is part of a bigger learning zone where the development of theoretical knowledge is a result of reflective processing of performance during practical work lessons and information acquired from lectures and self-study. The laboratory can be regarded as a Vygotskian learning zone of proximal development where more knowledgeable experts guide undergraduates, through scaffolded practical work, from a point of being novices and having limited knowledge to a point where they have developed skills and a better understanding of the topic they experiment on. Furthermore, practical work as an activity itself can be regarded as the starting point of a bigger learning zone of proximal development where undergraduates, through reflection from self-studying and information received in lectures, can potentially reach a more advanced level where they can process information by, for instance, writing a reflective laboratory report, and reach a satisfactory and scientifically-backed understanding of the material taught.

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