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Making it work: Practical work in tertiary Life Sciences

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Abstract

Practical work has been regarded for long and, as argued in this paper, unquestionably a fundamental component in the teaching and learning of biology-related sciences across all educational levels and an integral component of most, if not all, degree programmes in the Life Sciences (LS) in Higher Education institutions around the world. Whilst there are claims attributing educational benefits to practical work for LS undergraduates as per its effectiveness in promoting the development of conceptual understanding and practical skills [1, 2], these sometimes are either not empirically tested, or, for many reasons, seem overly ambitious. This almost *a priori* and unquestionable effectiveness of practical work - to that extent that its devoid in LS degrees is virtually unimaginable [3] - points to the need for a more evidence-based approach on its role in supporting undergraduates' learning and thus its necessity in LS undergraduate curriculum. This need is more critical especially when practical work instruction is very expensive, both for academic personnel, laboratory equipment, reagents and supplies during an academic year. This paper reports on findings of a mixed-methods case study conducted with LS undergraduate students in the UK to examine the effectiveness of practical work in conceptual understanding and development of practical skills. Observations and *in situ* informal assessment of undergraduates' conceptual understanding and skill development provided an objective empirical evaluation of the circumstances under which practical work is effective in these two areas. The preliminary findings of the study reported here showed that whilst the development of basic practical skills is satisfactory, conceptual understanding is, in most cases, lacking or insufficient. Deriving recommendations on how such an effective practical work lesson should be designed, staged and conducted are also reported.

Keywords: *Practical work in higher science education; Undergraduate practical work; Practical work in life sciences; Biology Education, Higher Biology Education*

1. Introduction

Practical work, defined as a wide range of hands-on activities "which prompts thinking about the world in which we live" [4] and as a "… learning experience in which students interact with materials or with secondary sources of data to observe and understand the natural world" [5], has been regarded as an essential component of science education across educational levels. It is seen as central in the teaching and learning of sciences since its use has, in many cases unquestionably as argued in this paper, been advocated for the facilitation of theoretical concepts and the scientific method understanding, development of laboratory and fieldwork skills and scientific inquiry [1, 2]. Despite the widespread use of practical work as a teaching and learning strategy, claims attributing educational benefits to practical work are not always empirically tested, or, for many reasons, seem overly ambitious.

In higher science education, research on the effectiveness and the conditions under which practical work promotes the development of laboratory skills and whether it works in connecting theory to practice is limited and in the field of life/biology sciences scarce. The almost a priori and unquestionable effectiveness of practical work points to the need for a more convincing and evidence-based approach on its role in supporting undergraduates' learning and thus its necessity in the curriculum. This need is more critical especially when taking into consideration the time and financial resources demanded for conducting it. Empirical evidence should be considered and evaluated to ensure that the benefits of practical work, at least, outweigh those of other teaching and learning approaches.

1.1 Study Aim and Purpose

The aim of the work reported on this paper was to examine the effectiveness of practical work in higher biology education in two areas, namely conceptual understanding, and development of practical skills. The purpose was to empirically test whether practical work is effective in these areas and if so how. In doing so, and rather than asking whether practical work in general constitutes an effective teaching and learning strategy in these areas, the Theory of Meaningful Learning [6, 7] was utilised as it provides a framework for an understanding of the way students need to be engaged in teaching and learning activities through interaction with worthwhile tasks for meaningful learning to take place. Meaningful learning occurs when students are exposed to experiences that integrate aspects of learning such as the cognitive, psychomotor, and affective domains [6]. Students can engage in a meaningful way with practical work by applying scientific thinking, conceptual understanding and appropriate technical methodologies to their subject of study than through an approach of rote learning that merely involves the memorisation and fails to appreciate its practical application.

The research questions that guided the part of the study reported in this paper are:

1. Is practical work effective in enabling undergraduates do what intended?
2. Is practical work effective in enabling undergraduates learn what intended?
3. Does practical work contribute towards meaningful learning?

2. Methodology

This study evaluated the learning objectives and aims set by academic staff to measure the effectiveness of practical work in promoting conceptual understanding and skill development in Life Sciences undergraduate courses. Under their supervision, the experiment protocols were examined and specific questions with accepted answers were formulated for an evaluation of conceptual understanding. A modified version of the Practical Activity Analysis inventory instrument [8, 9, 10] was utilised to evaluate the effectiveness of practical work, with a focus on effectiveness at (Fig.1). In addition,:

> Level 1 (Did undergraduates do what they were intended to do and see what they were intended to see?) and
>
> Level 2 (Did undergraduates learn what they were intended to learn?)

2.1 Research instrument and study sample

The Meaningful Learning in the Laboratory Instrument [7] was adapted to assess opportunities for meaningful learning in the cognitive and affective domains. The study was undertaken at a university department of Life Sciences in the United Kingdom at the beginning and end of the first and second semester of the academic year. The meaningful learning questionnaire investigating undergraduates' experiences and expectations while doing practical work was administered before the beginning of the academic year and at the end of the semester. Their actions as well as their thinking and ideas were assessed informally during observations using the questions developed from the protocols developed. Additionally, undergraduates were asked about their recollections on previous practical work lessons.

For the recruitment of participants, an opportunistic sampling strategy was used. Data were collected from undergraduate students by monitoring and interviewing them while engaged in practical work tasks during 18 laboratory lessons. The MLLI was distributed to undergraduates from Year 1 (n=256) and Year 2 (n=211).

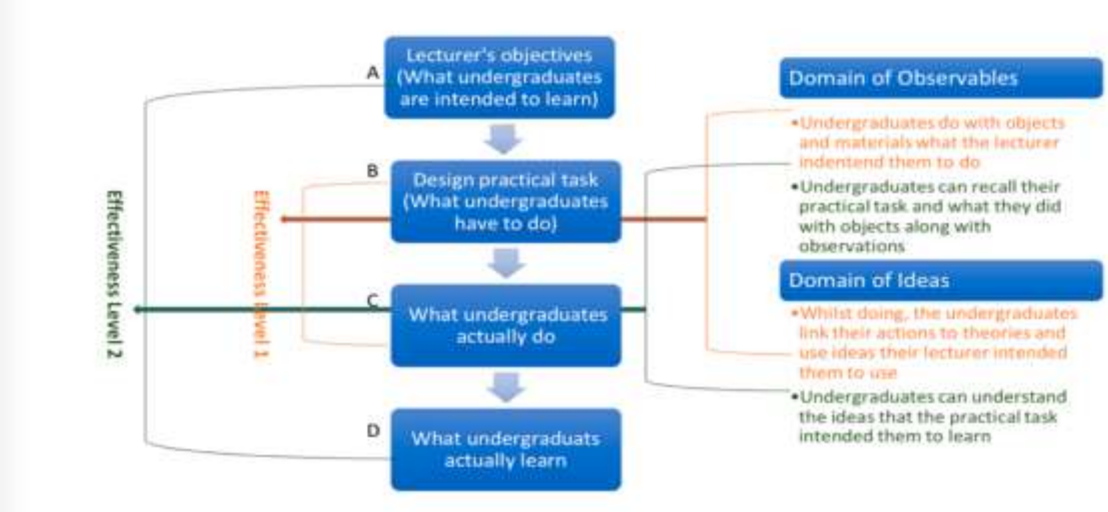

Fig 1. Theoretical model for the effectiveness of practical work [8-10].

3.Findings

3.1 Skill Development

The research study showed that skill development was a key component of the observed practical work lessons. Undergraduates were mostly trained during practical work on how to operate laboratory equipment and follow procedures. This approach was aligned with the learning objective and general aims of practical work prioritised in the university department.

The findings demonstrated that practical work was effective at Level 1, as undergraduates were able to complete the experiments as undergraduates could do what they were intended to do. However, the effectiveness of skill development was shown to be dependent on the availability of staff and teaching space and time as guidance and direction was required by members of staff particularly for Year 1 undergraduates and the transitioning to Year 2. Repetition, supervision and gradual progression was key in this process and as the findings showed, skills development was prioritised for career training purposes and was treated separately from other areas like the development of conceptual understanding.

3.2 Conceptual Understanding

Findings showed that conceptual understanding was not emphasised in either Year 1 or Year 2 practical work lessons. The development of understanding of concepts which is among the common aims of practical work [1, 5], was not among the learning objectives or departmental goals for practical work. Undergraduates were only able to understand the underlying theories and ideas in rare occasions and only when thorough and additional guidance was offered verbally during the practical work activities.

There is thus no evidence that undergraduates could link the domain of observables to the domain of ideas independently while limited evidence showed that this is achievable through talk and guidance in making the link. This provision of theoretical scaffolding relevant to the practical work merits further investigation to convincingly confirm or reject its beneficence in assisting the meaningful linking of scientific concepts to the manipulation of objects and observables and *vice versa*.

3.3 Meaningful Learning

The study findings also showed that undergraduates had positive feelings about the affective aspect of their laboratory experiences, but they expected and seek more opportunities for what the life science department does not prioritise, namely cognitive engagement and the doing of ideas. Meaningful learning entails the active participation in scientific processes as well as the development of cognitive skills such as independent thinking and the ability to link concepts across domains [6, 7].

4. Conclusions

Meaningful learning is more likely to occur in practical work when opportunities for talk are provided, and certain conditions are met. A well-structured lesson, assistance by members of staff, opportunities to apply practical work to real-life scenarios, direct and scaffolded connections to relevant theories and a positive learning environment all contribute to promoting meaningful learning in the laboratory while also empowering students to take ownership of their learning and become more independent in thinking conceptually when doing practical work. Lack of design and alignment with learning objectives as well as miscommunication of these to the students may be problematic and ineffective in promoting student meaningful learning. Also, practical work that is not well-designed or integrated with the course and meets the expectations of the students may also not be effective.

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