New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION


Does it really Work then? Practical Work in Undergraduate Science Education

CONSTANTINOU Marina (1), ABRAHAMS Ian (2)

University of Lincoln, United Kingdom (1)
University of Lincoln, United Kingdom (2)

Abstract

Many find it impossible to think of science education without practical work, stating that it is an essential part for effective teaching. Whilst there is much research in the area of practical work in secondary school there has been little research on how practical work enhances undergraduate students' conceptual knowledge and motivation as part of their science degree syllabus.
This case study research will be conducted at a university in England and will explore the effectiveness of practical work in terms of developing conceptual understanding, and its affective value in terms of motivation and personal interest in biology, chemistry and physics amongst undergraduate students. A presentation of the associated literature is presented along with the rationale behind the research.

Keywords: *Practical work, undergraduate, tertiary, sciences, effectiveness, affective value*

1. Introduction

A number of educators have directly related the teaching of sciences with the performance of practical tasks, deeming the two as inseparable [1] [2]. Whilst a big part of the literature has been concerned with practical work in secondary education, there has not yet been enough research on the impact of practical work in the teaching of sciences at university level [3]. Moreover, there is a lack of empirical evidence on how practical work contributes to the understanding of science concepts and undergraduates' motivation during their studies. Apart from being financially more expensive that alternative methods of teaching, practical work requires a lot of time and effort. Financial resources invested in equipment and consumables and in appointing trained laboratory staff and going through bureaucratic procedures concerning ethical clearance and health and safety should at least carry advantages that outweigh lecture-based science teaching [4]. In addition, practical work contributes to the increase of tuition fees for international students between science degrees and those in art and social science [5], as practical work is one of the most costly aspects of science education [6]. Despite claims that practical work does motivate and contribute in the understanding of science knowledge [7] ,albeit many of these claims lack research–based evidence, a more critical view has emerged showing no evidence of correlation between practical work and science conceptual understanding [8,9,10]. Furthermore, although there have been very few studies into the effectiveness of practical work at university level, none of these provide any support for the suggested purpose of practical work apart from them being an important part of the science syllabus [11] [12].
Taking into consideration that for undergraduate students, science is being studied by choice, in contrast to secondary school students who, in the Untied Kingdom, are compulsory required to study sciences up to the age of 16, it is anticipated that practical work might motivate undergraduates to study science as it has been reported that practical work is one of the most enjoyable aspects of studying science [13].
The purpose of practical work and the arguments concerning conceptual knowledge and affective value are now considered along with the rationale behind the research study being conducted.

1.1 The purpose of practical work

Much of the literature regarding practical work has been concerned with secondary education. However, it has been argued that the findings can be similarly applied to university level education and that the purpose of practical work at university has similar themes with objectives in secondary education [14]. A seminal study by Kerr [15] shed light on the aims of practical work in secondary education by providing teachers' opinions on the importance of objectives concerning practical work in ranked order. The findings in regards to the objectives of practical work by Kerr [15] included:

1. To improve and promote science learning and enhance knowledge to aid comprehension

2. To foster laboratory and scientific skills (e.g. observations, recording, measuring, using the microscope)
3. To develop scientific thinking (e.g. open-mindedness, observing, critical thinking, problem solving)
4. To motivate and enthuse pupils, stimulating enjoyment
5. To promote the understanding of the scientific method.
6. To make theories more real through tangible experiments

With regards to university level education, Reid and Shah [16] discussed the main objectives of practical work presented in thematic categories below:

Skills: Application of different skills in different contexts, understanding data, Getting familiar with equipment

Thinking scientifically: Application of knowledge in different contexts, Critical problem solving, Designing experiments

Affective value: Promoting confidence, Promoting interest, Motivating

Learning: Illustrating material presented in lectures

The main difference between secondary, and undergraduate, level science objectives is that motivation is not prioritised in the latter as, according to a survey asking graduates and practicing scientists to rank objectives based on importance, motivation was ranked the lowest in contrast to the acquisition of practical skills which was ranked among the highest aims [17].

2. The effectiveness of practical work

2.1 The cognitive argument

Based on Kerr's [15] objectives, the cognitive argument is concerned with practical work improving science learning and enhancing knowledge. It is argued that practical work can promote understanding in sciences by allowing students to visualise, in the form of experiments, material taught in class [14]. Admittedly, there is a difference between doing a practical activity and understanding a practical activity, and therefore a practical task done incorrectly can leave students confused. In the absence of guidance, students can leave their practical class with misconceptions that could affect their learning instead of supporting it. Indeed, studies [10] report that when students were tested using pen and paper examinations there was no evidence of conceptual understanding developed by practical work since it would be unrealistic to expect conceptual learning to be directly attributed to solely performing practical tasks. In an experiment, students usually see what they want to see since their pre-conceived ideas are influencing their interpretation [18]. Furthermore, it has been reported that practical work, instead of improving the understanding of science concepts, only allowed students to recall details from experiments involving unusual sounds or visuals [13]. With regards to studies concerned with undergraduate students, results showed that even though open-ended practical work, reflecting real science research, was incorporated into lectures, examination results remained constant despite an increase in the difficulty levels of the examinations [11]. Similarly, results from a study with introductory physics university students showed a correlation between conceptual enhancement and experimentation in comparison to traditional classes [19]. Furthermore, practical work enables students to experience what they have been taught theoretically in class through the subsequent use of hands-on activities. Even though conceptual understanding might not be completely achieved, since practical work has not been reported to have any further advantages compared to other didactic methodologies, there is no evidence suggesting that it should be excluded from a science curriculum [9].

2.2 The Affective argument

According to Kerr [15] practical work promotes students' interest in learning sciences. Consequently, it has been asserted that interested students will be actively involved in practical tasks and will therefore remember information in comparison to traditional taught classes [20]. However, it is unclear whether students' expressions of enjoyment towards practical work is based on its worth as a didactical tool or as an activity that is being run in a more relaxed pace than a traditional lecture [9] where they could

possibly be passively copying material from the board. Students have previously expressed their enjoyment for practical work since it promotes collaborative work and allows them to work in their own pace [9]. Confirming this, it has been reported that one of the reasons students felt motivated was that they had a sense of control while doing experiments [10], something that can be counterproductive if students start concentrating on non-substantial issues. However, students reported to be excited when they were doing experiments that were confirming previously stated theories, contradicting the true nature of being a scientist [21]. In this respect it should be acknowledged that the way students perceive practical work is different from the affective value practical work provides *per* se, since students' perception might be influenced by factors including the style of a practical lesson or their ability to understand and relate concepts learned, to their everyday life [9]. In support of this view, undergraduates' motivation was found to be highly affected by the style of the practical work which influenced their perceptions of the lecture [11]. However, students' satisfaction did not increase when more time was spent in practical activities [8]. This was explained [10] in terms of practical work primarily only developing short-term, non-eduring, situational interest, rather than motivation which was the term teachers mistakenly used when explaining what they saw as the affective value practical work on their students.

3. The research

As a result of the aforementioned findings deriving from previous research and the gaps identified in our understanding of the value of practical work at university level, a study will be conducted exploring the effectiveness of practical work in terms of developing conceptual understanding and its affective value in biology, chemistry and physics, the three pure sciences, amongst undergraduate students. The main objective of the research is to focus on finding answers to the main research questions being:

1. Is practical work effective in enabling undergraduates to learn science concepts?
2. Does practical work have an affective value?

Only with more comprehensive research will a clearer picture be formed as to the effectiveness and affective value of practical work in university education, where undergraduates are attending by choice. The results of this study will enable the use of practical work to be adjusted so as to maximise the support in provides to students in terms of learning conceptual material and in developing enduring motivation towards science.

References

[1] Millar, R. & Abrahams, I. "Practical work: making it more effective", School Science Review, 91(334), 2009. 59-64.
[2] Sturman, L., Ruddock, G., Burge, B., Styles, B., Lin, Y. & Vappula, H. "England's achievement in TIMSS 2007: National report for England", Slough: NFER, 2008, *156*.
[3] Osborne, J. "Practical work in science: Misunderstood and badly used", School Science Review, 2015, 96(357), 16-24.
[4] Reid, N. & Shah, I. "The role of laboratory work in university chemistry", Chemistry Education Research and Practice, *8*(2), 2007, 172-185.
[5] The complete university guide. "Tuition fees for international students (2016-2017)" 2018.
[6] Retrieved from https://www.thecompleteuniversityguide.co.uk/international/studying-in-the-uk/tuition-fees
[7] Atkins, M. & Brown, G. "Effective teaching in higher education", London, Routledge, 2002.
[8] House of Commons Science and Technology committee "Science Education from 14 to 19. 2001-2002.V1", 2002. Retrieved from https://publications.parliament.uk/pa/cm200102/cmselect/cmstech/508
[9] White, R. T. "The link between the laboratory and learning", International Journal of Science Education, 1996, 18(7), 761-774.
[10] Lunetta, V. N., Hofstein, A. & Clough, M. P. "Learning and teaching in the school science laboratory: An analysis of research, theory, and practice", Handbook of research on science education, 2007, 393-441.
[11] Abrahams, I. "Practical work in secondary science: A minds-on approach",London, A&C Black, 2011
[12] Brownell, S. E., Kloser, M. J., Fukami, T., & Shavelson, R. "Undergraduate biology lab courses:

Comparing the impact of traditionally based cookbook and authentic research-based courses on student lab experiences", Journal of College Science Teaching, 2012, 41(4)
[13] Hubbard, K. E., Brown, R., Deans, S., García, M. P., Pruna, M.-G., & Mason, M. J. "Undergraduate students as co-producers in the creation of first-year practical class resources",Higher Education Pedagogies, 2017, 2(1), 58-78.
[14] Abrahams, I., & Millar, R. "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, 2008, 30(14), 1945-1969.
[15] Wang, W., & Coll, R. K. "An investigation of tertiary-level learning in some practical physics courses", International Journal of Science and Mathematics Education, 2005, 3(4), 639.
[16] Kerr, J. F. "Practical work in school science: An account of an inquiry sponsored by the Gulbenkian Foundation into the nature and purpose of practical work in school science teaching in England and Wales", Leicester University Press, 1963
[17] Reid, N., & Shah, I. "The role of laboratory work in university chemistry", Chemistry Education Research and Practice, 2007, 8(2), 172-185.
[18] Boud, D. J., Dunn, J., Kennedy, T., & Thorley, R. "The aims of science laboratory courses: A survey of students, graduates and practising scientists", European Journal of Science Education, 1980, 2(4), 415-428.
[19] Driver, R., & Bell, B. "Students' thinking and the learning of science: A constructivist view", School Science Review, 67(240), 1986, 443-456.
[20] Hake, R. R. "Assessment of student learning in introductory science courses", PKAL Roundtable on the future: Assessment in the service of student learning, Duke University, 2002
[21] Dillon, J. "A review of the research on practical work in school science", King's College, London, 2008, 1-9.
[22] Johnstone, A. H., & Al-Shuaili, A. "Learning in the laboratory; some thoughts from the literature", University Chemistry Education, 2001, 5(2), 42-51.