Data-analysis in practical work, what do students know?

Freek POLS, Peter DEKKERS, Marc de VRIES
University of Technology Delft - SEC, Lorentzweg 1 – Room C108, 2628 CJ Delft

Although literature indicates that practical work is often not efficient, it is still common practice in secondary school physics. In order to improve the learning outcomes of these activities, we investigated students' ability to process experimental data and draw conclusions out of these datasets using thinking-out-loud and practical tasks. We expected that the lack in data-analysis skills may be a major barrier in learning from experiments. Both the activities show that students encounter various problems, often do not know how to process data and draw valid conclusions. A lack of data-analysis skills may therefore be a barrier in learning indeed.

1 Introduction

Practical work is frequently carried out in secondary school physics for various reasons. Although these activities illustrate the empirical nature of physics [1], enhance the link between theory and practice [2] and learn students how to work scientifically, they often have limited learning outcomes. The same results could be achieved with less costly and time consuming methods [3,4]. The challenge is to improve the way practical work is executed.

When the practical task focuses on establishing a relationship between two physical quantities, a proper data-analysis is essential. However, students usually encounter various problems and difficulties [5]. If students do not know how to process data to establish a quantitative relationship, the learning goals may not be achieved. Hence, the lack in data-analysis skills might be a reason for the limited learning outcomes.

In this study we investigated students' ability to process experimental data and draw conclusions out of datasets. In earlier studies the focus has been on students' knowledge of the validity and reliability of data [5,6] but these studies did not investigate the next step in which the processing of data is central. The main question in this study is: *How do students who have chosen a science-based lesson program, analyse experimental data and what is the quality of that analysis?*

2 Theoretical background

At the age of 15, students in the Netherlands enter upper secondary education and choose one of four profiles. Science is central in two of these profiles and students are therefore expected to work more independently when doing practical work. Various physics curricula describe which data-analysis skills students at that age should possess [7,8]. Using these curricula, ten data-analysis skills students ought to possess are distilled, see table 1. In this study, we assess students' ability to use these skills.

Table 1: According to literature, students aged 15 should possess these ten data-analysis skills [7,8]

1	Visualise data graphically
2	Use theoretical models to infer whether a line should go through the origin
3	Draw a line of best fit through a data set and articulate that choice
4	Distinguish a linear relation from others
5	Qualitatively describe a dataset or trend
6	Qualitatively describe similarities and differences between datasets
7	Draw a conclusion which is supported by the dataset
8	Indicate restrictions concerning the data-analysis and conclusions
9	Estimate the value of a point within the range of available data (interpolation)
10	Estimate the value of a point outside the range of available data (extrapolation)

3 Method

This qualitative study was conducted in the first two months of the schoolyear 2017/2018, with two different physics classes and a total of 51 students. Student pairs analysed three graphs in a thinking-out-loud task and executed three in-class practical tasks in which experimental data was processed to establish relationships between physical quantities. Data were collected by using audio recording and using pre-set lab journals in which students showed their know-how. The quality of their analysis was determined using the Toulmin argumentation model [9], scientific conventions regarding constructing graphs [10], and a protocol for analysing experimental data [11].

4 Results

Almost every student was able to visualise the data in a graph that meets the scientific requirements. However, students perceived describing the dataset as difficult. This is reflected by the fact that they often did not mention all essential features of the dataset. Determining and consecutively using the line of best fit also caused many problems. Students hardly knew what to do after the data were visualised. They often drew a straight line through a dataset where a curved one would fit better. When extrapolating, they frequently used a directly proportional relation even though they had previously indicated that it was not a linear relationship. Their conclusions were supported by the data most of the time but remained superficial and incomplete.

5 Conclusions and implications

Although the various physics curricula indicate what teachers may expect of students, the students hardly master the aforementioned data-analysis skills. It is therefore not surprising that the learning outcomes of practical work are limited when students lack the essential skills but still have to apply them independently. We therefore recommend to develop these skills before, gradually, executing more 'open' practical tasks. Some opportunities to enhance these particular skills were found in this study.

References

[1] R. Millar, J.F. Le Maréchaland A. Tiberghien, (1999). Mapping the domain: Varieties of practical work. In J. Leach & A. Paulsen (Eds.), *Practical work in science education - Recent research studies* (pp. 33-59). Roskilde/Dordrecht: The Netherlands: Roskilde University Press/Kluwer.

[2] R. White, (1991). Episodes, and the purpose and conduct of a practical work. *Practical science,* 78-86

[3] D. Hodson, (1990). A critical look at practical work in school science. *School science review, 70*(256).

[4] V. N. Lunetta, A. Hofstein, and M.P. Clough, (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. *Handbook of research on science education*.

[5] Z. Kanari, and R. Millar, (2004). Reasoning from data: How students collect and interpret data in science investigations. *Journal of Research in science teaching, 41*(7), 748-769.

[6] R. Gott, and S. Duggan, (1995). Investigative Work in the Science Curriculum. Developing Science and Technology Education.

[7] NRC, (2013). Next generation science standards: For states, by states.

[8] W. Ottevanger, F. Oorschot, F. Spek, (2014). *Kennisbasis natuurwetenschappen en technologie voor de onderbouw vo: Een richtinggevend leerplankader*: SLO (nationaal expertisecentrum leerplanontwikkeling).

[9] S.E. Toulmin, (2003). *The uses of argument*. Cambridge University Press.

[10] S. Lachmayer, C. Nerdel and H. Prechtl, (2007) Modellierung kognitiver Fähigkeiten beim Umgang mit Diagrammen im naturwissenschaftlichen Unterricht. *Zeitschrift für Didaktik der Naturwissenschaften,* 13.

[11] R. Boohan, (2016). The Language of Mathematics in Science: A Guide for Teachers of 11-16 Science. Hatfield: Association for Science Education.