Multiple Representations in Laboratory Data Analysis

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Abstract. The interpretation of data and graphs are central practices in science. Therefore, an important skill needed in the physics laboratory is the ability to process raw data obtained from experiments. The main question that the presented study focuses on is how students are dealing with multiple representations of data received from physics laboratory experiments. On one hand there are a lot of benefits in using the multiple representations, on the other hand it may pose a difficult challenge for learners. 77 students participated in this study. The findings show that students have significant difficulties in translating information from one representation to the other (for example, visual and analytical), and in dealing simultaneously with three different visual representations.

Keywords: physic's laboratory; laboratory data processing; multiple representations

Introduction

The interpretation of data and construction and interpretation of graphs are central practices in science (Bowen & Roth, 2005), therefore an important skill needed in the physics laboratory is the ability to process raw data obtained from experiments. From Bowen's & Roth's point of view, "Physical phenomena are translated through consecutive inscriptions that may include, in increasing order of complexity, such re-presentations as maps, lists, tables, totals, means, graphs and equations" (pg. 1064). In addition, in the process of developing theories, scientists also manipulate the data translating one representation into another.

Many studies highlight the benefits learners may reap from using multiple representations. To name a few, Ainsworth (1999) argued that a known representation may help understand an unknown representation, and that representations may complement each other; Petre, Blackwell and Green (1998) explained that mentally moving between representations forces learners to look beyond the borders and details of a certain representation; Dori and Sasson (2008) found that the ability to move back and forth between verbal and visual representations improved both graphic and conceptual abilities of learners in chemistry. On the other hand, working within a multi-representational learning environment may pose a difficult challenge for learners. Such environments require: 1) understanding the syntax of each of the representations, 2) understanding which part of the topic is being represented, 3) identifying partial correspondence between representations, and 4) translating between representations by finding the similarities and differences in the two systems of representation (van der Meij & de Jong, 2006).

The main research question that this study focuses on is how students are dealing with multiple representations of data received from physics laboratory experiments.

Methodology

The sample included 77 students: 28 first-year engineering college students, 24 first-year physics university students and 25 university students, participants of teaching certificate program, studying to get a teaching certificate in physics, all of them having at least a bachelor's degree in physics or engineering. All the participants filled out the questionnaire at the end of their physics laboratory class.

The "raw data analysis" questionnaire, which was developed for our previous study, was used (Eshach & Kukliansky, 2007). It included 20 multiple choice questions referring to different parts of an experiment on Newton's second law. The questionnaire was evaluated by five experts and showed internal consistency reliability (Alpha Cronbach) of 0.69.

Results

The results showed that the participants had difficulties in translating from one representation to another and in dealing simultaneously with several representations.

About a fifth of the participants chose wrong linear graphs instead of the parabolic one describing the cart's movement. About a fourth of the participants experienced difficulties in questions requiring reading of kinematics graphs', where visually represented information needed to be translated to a numerical representation. For example, difficulties were found in calculating the distance traveled by the cart during a time interval specified by two time points.

Another example demonstrating the need, and therefore the difficulty, of dealing simultaneously with three different visual representations, was a graph which included a scatter diagram describing the results of the experiment's measurements, the regression line which was calculated and drawn between the points, and the error bar which was calculated and marked around each of the points. The question dealt with the handling of deviant measurements – measurements relatively far from the measurements' regression line. The participants were asked whether, when applying the regression line, two relatively distant points (from the regression line) needed to be taken into account. One of the points was within the range of the error bar and one was not. Visual considerations alone might have lead to ignoring the two points because they are "too distant" from the line which passes through all the other points. Visual considerations might also have lead to the points taken into account and to the decision that the regression line should be influenced by them. The majority of the participants (over 70%) chose one of these two wrong options. The correct answer in this case is that the point within the error bar needs to be included, while the one outside the error bar must be re-measured.

Discussion

A possible explanation for choosing the linear graphs instead of the parabolic one is that the participants were influenced by the movement which took place on a straight horizontal plane, and consequently, chose a graph which included straight lines. Again, this attests to students' difficulties in translating information from one representation to the next.

The difficulties revealed in the questions requiring reading of kinematics graphs' where visually represented information needed to be translated to a numerical representation fit the results of many studies in the domain of kinematics' graphs' representation (e.g. Beichner, 1994; Forster, 2004).

The interpretation of a graph as being a kind of a picture might be due to students' difficulty to 'translate' the distance-time graph to the real life, and instead making parallels between the basket's height and the graph's height. Also, the difficulty to extract the acceleration from a graph describing distance as a function of time, stems, probably, from the difficulty to extract a numerical value from a visual representation – indeed, in order to extract the acceleration one has to 'translate' the graph's slope and tie it to acceleration. In addition, the difficulty to choose a graph, which best describes the distance of the cart traveled during the experiment as a function of time, probably stems from the difficulty of conducting a number of sequential translations which this task demands: translating the distance traveled by the cart as a function of time to an analytical representation – a formula – and then translating it again from the formula to the description of the correct graph. This process can be described using Figure 1:

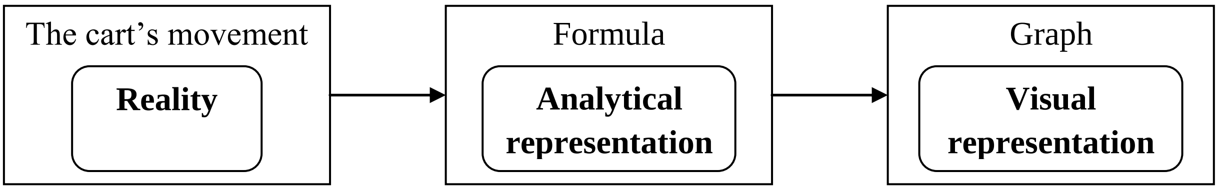

Figure 1. The translation process

It seems that students had difficulty to deal simultaneously with three representations and considered only two of them – the scatter diagram and the regression line – disregarding the error bar.

The cognitive challenge students face when processing laboratory data (e.g. manipulating raw data, simultaneously representing it in a variety of forms, moving from one representation to another) may explain the difficulties identified in this study which also concur with other studies conducted regarding the handling of multiple representations simultaneously (Arcavi, 2003). Indeed, the findings of this study show that even university students have cognitive difficulties in handling multiple representations. Physics lecturers as well as laboratory instructors should take these cognitive barriers into consideration when teaching in physics laboratories.

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