ANALYSIS OF SOME SELECTED FORCE CONCEPT INVENTORY TASKS USING EYE-TRACKING AND CORRELATION WITH SCIENTIFIC REASONING SKILLS

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Abstract

The aim of the research was the analysis of the problem dealing with solving of six Force concept inventory tasks by first-year university students using obtained eye-tracking data. Some characteristics like attention maps and sequences of fixations provide a deeper insight into the students' approaches to the tasks verifying their conceptual understanding to Newtonian mechanics. It can be confirmed the correctly answering students found the correct solutions more straightforwardly making their decision between fewer options. This is also supported by the analysis of fixation numbers and fixation times. The results show differences in the way novices and experts process questions and enable to identify some persistent misconceptions.
Keywords: *eye-tracking, introductory physics course, scientific reasoning, solving tasks*.

Introduction

FCI (Force Concept Inventory) is probably the most commonly used diagnostic test to assess a student's knowledge of Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992) and there are a number of studies on analysing and revising FCI. However, it is difficult but on the other hand of great interest to investigate what strategy students are using while trying to solve FCI questions. Measurement of eye movements provides some information about the underlying cognitive processes and visual attention during problem-solving. In recent years, eye-tracking has been increasingly used to explore how high-school or university students solve the problems from various parts of physics – see e.g. (Han, Chen, Fu, Fritchman, & Bao, 2017; Kekule & Viiri, 2018; Ohno, Shimojo, & Iwata, 2016; Susac, Bubic, Planinic, Movre, & Palmovic, 2019; Viiri, Kekule, Isoniemi, & Hautala, 2017).

The aim of the research was to bring another small step further into understanding students' minds, and in the evaluation of the problem-solving processes at the level of an undergraduate introductory physics course.

In science, technology, engineering, and mathematics education there is also increased emphasis on teaching goals that include not only the learning of content knowledge but also the development of scientific reasoning skills. The Lawson classroom test of scientific reasoning (LCTSR) is a popular assessment instrument for scientific reasoning (Lawson, 1978) with some of its components – proportional thinking, probabilistic thinking, correlational thinking, hypothetical-deductive reasoning. The research questions of the research were:

- Is it possible to find a correlation between the conceptual understanding of Newtonian mechanics and general scientific reasoning skills;
- Is it possible to confirm the correlation presented between students' scientific reasoning measured by LCTSR and conceptual understanding of the force concept obtained (Sriyansyah & Saepuzaman, 2017), and the outcomes of the study by (Bao et al., 2009a; Bao et al., 2009b).

Research Methodology

The Lawson classroom test of scientific reasoning was completed by twenty-one perspective physics teachers programme students of the Faculty of Science, Palacky University Olomouc, in their first year of their university bachelor study at the beginning of the first semester and once more eight weeks later. From the FCI test 6 multiple choice tasks were taken; all those selected problems included important graphical information presented through a picture. The students solved the problems after completing the corresponding parts within an introductory course of classical mechanics (8 weeks of lectures and seminars instruction), the problems covered the kinematics, the first and the second Newton laws and the motion in the homogeneous gravitational field. Two of the tasks showed as rather difficult (with the item difficulty index values .29 and .19 respectively).

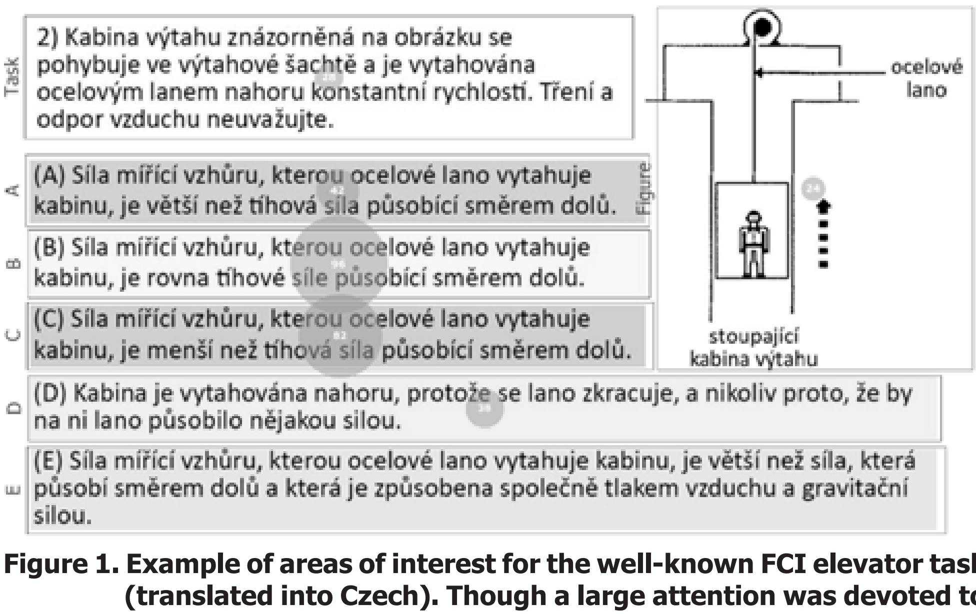

Figure 1. Example of areas of interest for the well-known FCI elevator task (translated into Czech). Though a large attention was devoted to the right answer (B), the wrong distractor (C) connected with a frequent misconception gets also quite a large spot.

For the measurement the Gazepoint GP3 eye tracker with the sampling rate 60 Hz and spatial resolution (RMS) 0.1 degree was used. The problems were displayed on a computer screen, placed in front of the participants, who were asked to read and solve each task silently, and say the answer aloud when they have solved the problem. There was a time limit of 15 min to complete all the 6 tasks. The data were then processed and analysed by Ogama program. Several areas of interest for each task (questions, multiple choice distractors and related pictures were defined. Attention maps for the areas of interest and sequences of fixations for each problem and all participants were compared (see e.g. Figure 1 showing count of fixations for each area for one student). Also, some eye-tracking measures were calculated including viewing times, numbers of fixations and average fixation durations.

Research Results

A statistically significant correlation between students' scientific reasoning measured by LCTSR and conceptual understanding of force concept has not been confirmed, the results in both our tests have Spearman's rank correlation coefficient 0.219. It was found out that for our students the rigorous learning of physics knowledge is not so strongly affected by their general scientific reasoning ability.

The eye-tracking data shows, that on average the students choosing the right answer come to their conclusion more smoothly and in a shorter time than those who are hesitating and take the wrong distractor in the end. This is confirmed by a moderate correlation between the test score and path velocity of their eye-tracking in pixels per second (Spearman's rank correlation coefficient .492).

Conclusions

The outcome of the eye-tracking analysis confirmed that more successful students tended to focus faster and spend more time on task-relevant details, sometimes they were able to proceed to the right answer straightforwardly after reading the main part of the question. Due to the test problem distractors, we were also able to identify persistent misconceptions connected with the first Newton law for uniform rectilinear motion and the composition of motions in a uniform gravitational field.

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