Eye movement study of mechanics problem solving using multimodal options

Jouni VIIRI, Jasmin KILPELÄINEN

Department of Teacher Education, University of Jyväskylä, 40140 Jyväskylä, Finland

Martina KEKULE

Department of Physics Education, Charles University, Ke Karlovu 3, 121 16 Praha , Czech Republic

Eizo OHNO

Faculty of Education, Hokkaido University, Kita-11, Nishi-7, Kita-ku,, Sapporo, Hokkaido, 060-0811 Japan

Jarkko HAUTALA

Department of Psychology, University of Jyväskylä, 40140 Jyväskylä, Finland

Abstract. We used eye-tracking method to uncover students' approaches to solving the physics task with different representations and the differences between students who answered correctly and those who answered incorrectly when solving the problems. Twenty-four upper secondary school students from Czech Republic, Finland and Japan took part in the study. We found that students who preferred either text or graph representations watched the options differently but the used both representations to be sure of their solution. Interviews revealed typical misconceptions about force concept. Implications for physics instruction are presented.

1 Introduction

Problem-solving is an important interest of physics education research. To uncover students' problem solving approaches, in recent years problem solving has been investigated also by the eye-tracking method (e.g. [1]). Tracing attention of a watching person allows to get deeper insight into his or her problem-solving strategies. Multiple-choice tasks are typical in studying students' knowledge. Mechanics has been a popular subject of eye-tracking studies in physics education. Researchers have been interested in students' problem solving when problems are posed not only in verbal form but in different representations, e.g. text, graph, table [2].

The study focused on two main issues: 1) We follow differences in approaches to solving the physics problems between correctly and incorrectly answering students. 2) We focus on students' preference of graph and verbal representation.

2 Methods

Participant students (N = 24) were from high schools in Czech Republic, Finland and Japan. Data collection was carried out in spring 2018 during school days. We used following eye-tracking equipment: the SMI RED250mobile, 250 Hz sampling frequency (FIN), the TX300 Tobii, 300 Hz (CZ) and Tobii Pro X2-60, 60 Hz (JPN). Data collection had four stages:

1. Students took a nine question multiple-choice pre-test of their conceptions of Newton's 1st and 2nd laws. Based on the pre-test results a sample of students were chosen so that we had students who were very success full, success full or unsuccessful in the test.

2. Eye tracking test consisted of four qualitative items related to Newton's 1st and 2nd law. In every item, the stem was in text on the left side of the screen. The multiple-choice alternatives

were presented in both the text and graph representations. We varied the order of text and graph forms so that in some items the text was on the left side and the graph on the right side and in other questions in the reversed order (text on the right and graph on the left).

3. Short Likert scale questionnaire about graph – text preference was administered.

4. Students were interviewed first just showing them the items. Secondly, students were shown their gaze plot video and they commented on their solution process.

Based on obtained raw data heat maps and gaze plots were created. Furthermore, on defined AOIs (areas of interest) fixations duration and number of fixations was counted for two students group – those, who answered a task correctly and those, who did not.

3 Results

We provided both quantitative analysis based on time spent on the AOIs and qualitative analysis based on gaze plot and heat maps of each participant. .An example of the qualitative analysis based on heat maps is shown in Fig. 1. In figure a) student has watched more on the text representation of the multiple choices and the student has looked for a long time on the key word "constant speed" in the stem. In figure b) is a heat map of a student who prefers graph representation but has also watched the text representation of the choice selected. Student seems to have been sure of the answer since he/she has only watched on the choice selected.

a) b)

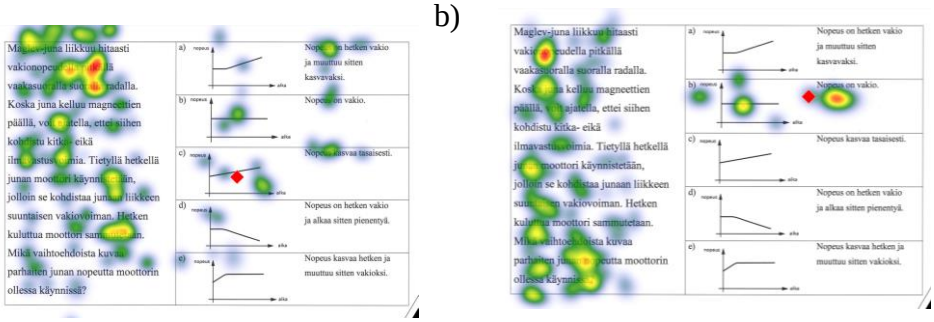

Fig. 1. Example heat maps. On the right is the stem and on the left are the multiple choice alternatives in text and graph representations. a) Heat map of a student who prefer text representation, correct solution; b) heat map of a student who prefer graph representation, incorrect solution.

The interviews reveal typical misconceptions, e.g. "when the force is double, then the velocity has to be double". But a student with correct answer commented his solution as "since in the space there are no other forces, when the motor pushes the rocket the rocket speed increases all the time". Students were astonished to see from the gaze plot how they had been looking at the problem. They were mostly unaware where they allocate their attention during the task.

4 Conclusion

The results can be used in physics education since they show what processes, representations and key concepts students use in answering the problems.

References

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[2] D.T. Treagust, R. Duit and H.E. Fischer (eds.), *Multiple representations in physics education*, Springer, Berlin, 2017.