Differences in solution process of incorrectly answering students solving R-FCI tasks observed by eye-tracking method

Martina KEKULE, Iva JAKUBSKA

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

Jouni VIIRI

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

Abstract. The paper presents qualitative analysis of students' strategies when they solve problems from mechanics. Particularly, 35 high school students solved 4 tasks mainly from R-FCI test and during solving the problems their gaze were recorded by the eye-tracker. Based on their gained gaze plots, we analyzed differences in approaches between correctly and incorrectly answering students. Moreover, we have found differences between incorrectly answering students which suggest different misunderstanding of Newton's laws.

1 Introduction

Solving multiple-choice tests is very common in the physics education field. In mechanics, Force Concept Inventory (FCI) test [1] is well-known and recently, a representational variant of the force concept inventory (R-FCI) was developed by Nieminen et al. [2]. For nine original FCI items two new isomorphic variants were formulated in different representations, e.g. text, graph or diagram. Administration of such a test in paper-pencil way means that we get students' final decision about their choice. In order to get deeper insight into students solving processes, we can apply eye-tracking method, which allow us to observe students' decision making. The method is possible to use for both qualitative and quantitative type of research design [3]. For example, Tsai et al. [5] focused on quantitative approach, Kekule [6] discussed qualitative approach used in PER.

Based on summarized data on defined area of interest we observed differences in approaches between correctly and incorrectly answering students [7]. Here we focused more on detailed qualitative analysis of gaze plots of the best and the worst performing students in the test and we want to demonstrate especially differences between the worst performers.

2 Methods

By the eye-tracking method we observed students when they were solving four tasks from mechanics, particularly three tasks from the R-FCI test [2] and one task was originally created for purpose of the test in the same manner as the three previous ones. All tasks were focused on understanding of Newton's laws; two on Newton's 1st law and two on Newton's 2nd law. The test basically consists of four different questions, each of them with options in three different representations: verbal, graph and motion map. All task stems appeared in written form. Additional short questionnaire about their performance and attitude to physics was administered to students.

High school students and students just enrolled in their first university year study took part in the study. Valid data from altogether 35 students were gained.

Students' gaze were recorded by TX300 eye-tracker with sampling frequency 300 Hz and raw data was analysed by TobiiPro 3.2 software.

Based on students' performance in the test, we chose the best and the worst performers (altogether four participants) for further qualitative analysis based on their gaze plot, i.e. plot of their fixations and saccades during solving the tasks. Especially, we will focus on differences between incorrectly answering students.

2 Results and conclusions

We have found different approaches between the best and the worst performers. Moreover, we have found differences between incorrectly answering students which suggest different misunderstanding of Newton's laws. See for example Fig. 1. The task was focused on understanding of Newton 1st Law and the last option e) is the correct answer. Participant no. 12 is obviously not interested in the correct answer at all, he paid only one fixation to the option. Whilst the other incorrectly answering student, participant no. 39, was thinking about the correct answer much more. Similar behavior of these two students we can observe also for the other tasks as well.

Presented results can help teachers in deeper understanding of students' thinking processes, and can improve their communication with the students about these typical problems in mechanics. Implications for teachers' communication in their praxis will be therefore provided as well.
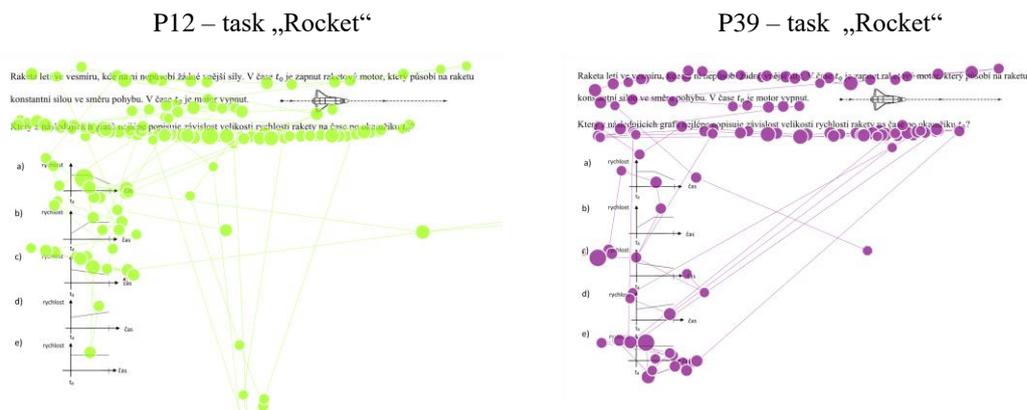
P12 – task „Rocket"　　　　　　　P39 – task „Rocket"

Fig. 1 Examples of gaze plots for two incorrectly answering students

References

[1]   Hestenes, D., Wells, M., and Swackhamer, G. Force Concept Inventory. *The Physics Teacher* **30** (1992) 141-158.

[2]   Nieminen, P., Savinainen, A., and Viiri, J. Force Concept Inventory-based multiple-choice test for investigating students' representational consistency. *Physical Review Special Topics – Physics Education Research* **6** (2010) 020109.

[3]   Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., and Van Dee Weijer, J. *Eye tracking*. Oxford university press, Oxford, 2015.

[4]   Madsen, A. M., Larson, A. M., Loschky, L. C., and Sanjay Rebello, N. Difference in visual attention between those who correctly and incorrectly answer physics problems. *Phys. Rev. Special Topics – Phys. Ed. Research* **8** (2012) 010122.

[5]   Tsai, M.-J., Hou, H.-T., Lai, M.-L., Liu, W.-Y., and Yang, F.-Y. Visual attention for solving multiple-choice science problem: An eye-tracking analysis. *Computers & Education* **58** (2012) 375–385. doi: 10.1016/j.compedu.2011.07.012

[6]   Kekule, M. Qualitative approach of eye-tracking research in science education In Dabaj, F. *Proceedings of International Conference on Contemporary Issues in Education Dubai*, UAE, (2015) 104-111.

[7]   Kekule, M., Viiri, J., Isoniemi, J., and Hautala, J. Uncovering the effect of task representation on students' problem solving by eye tracking *in Book of Abstracts, ESERA conference2017*, (2017) on-line.