Towards overcoming students' difficulties in understanding graphs

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Abstract. This study was designed to overcome students' difficulties in interpreting motion graphs and describing motion through graphs. We used tasks involving motion that can be observed in everyday life, such as a modified PISA racing car problem, and designed a short intervention. Eye-tracking technology was used to track participants' visual attention while they completed the tasks and analysed the supporting questions. The results highlight the challenges of responding too quickly and treating graphs as pictures. The findings underline the benefits of even a short intervention that encourages a reflective approach and addresses intuitive reasoning to improve students' understanding motion graphs.

Introduction and theoretical framework

Graphs are an essential tool for representing and analysing physical phenomena, as they allow for visualizing the relationships between different quantities. Both physics and mathematics education research has extensively investigated student difficulties with graphs, e.g. [1-4]. Eye-tracking methodology is also used to diagnose the students' difficulties [e.g. 5-7]

Psychological Dual Process Theory [e.g. 8] provides a perspective to physics and mathematics education for interpreting research results [9-10], paying attention to students' fast thinking, which results in intuitive wrong answers, versus slow thinking, which activates analytical thinking and self-monitoring. Our research aims to activate analytical and critical thinking to help students overcome difficulties in understanding motion graphs.

Research methodology

Our research question is: *How can we help students overcome difficulties in interpreting graphs? More specifically, how does a brief intervention designed to promote slow analytical thinking, as described by Dual Process Theory, affect students' comprehension of motion graphs?*

Participants in this study were undergraduate mathematics students in different years of study from Croatia and Poland.

First, students answered questions provided in problems focused on two directions of reasoning: from mathematical model to its interpretation (e.g. modified PISA mathematics item M159Q01, [11]) and from a description of real life situation to its mathematical model (e.g. modified stone problem, [7]). The set of tasks formed pre-test.

After each task from the pre-test, students were asked some additional short questions related to the situation presented in the task, which acted as heuristic cues for understanding and analysing the problem. After each such brief intervention, the students answered the same task again. The second attempt at each task formed the post-test.

Eye movements were recorded using the Tobii Pro X3-120 of the system with a sample rate of 120 Hz. The recorded eye movement data were analysed using Tobii Studio software. After completing the eye-tracking session, students also answered a brief written questionnaire in which they assessed their level of knowledge and skills in high school mathematics and physics. Finally, they assessed the difficulty of the tasks and shared opinions and doubts on them.

Findings and Conclusions

The students often chose the option which indicates treating the graph as a 'picture'. Results of the study are in line with previous studies that used dual-process theories (e.g. [8]) to explain why students who acquired the relevant knowledge and skills still tend to rely on their intuitively appealing (and often incorrect) ideas [9,10].

We have also shown that even brief intervention brings a significant improvement in the understanding of motion graphs. The additional questions about graphs can help students better understand the complex motion presented in the tasks. The impact of the additional questions lies not only in prolonging the time spent analysing the graph but mainly in effectively directing attention to the relevant parts of the graph.

These results confirm that it is necessary to design instructional strategies that address students' intuitive reasoning and promote reflective thinking.

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