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Constructing a diagnostic instrument for wave optics

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Abstract. As a part of a larger project, a 26-item Conceptual survey on wave optics (CSWO) was developed to serve as a post-test diagnostic instrument for assessing high school students'understanding of basic wave optics phenomena: interference on a double slit and optical grating, diffraction on a single slit and polarization. The construction of the CSWO included several cycles of testing and Rasch analysis. The final version of the test shows good targeting on the sample and good overall functioning.

1 Introduction

In Croatia, where physics is a compulsory subject in many high schools, the topic of wave optics is covered in the last year of studying physics, when students are 18-19 years old. The curriculum prescribes the following topics from the domain: interference on a double slit and optical grating, diffraction on a single slit and polarization. Previous PER research about students'difficulties with the mentioned domain was conducted on high school and university students [1-4] and showed that this is a difficult topic for both types of students and suggested that even the fundamental wave optics phenomena are not easily understood by them.

As a part of a larger research project aiming at developing an inquiry-based teaching approach for wave optics topics in high schools a new diagnostic instrument on wave optics (Conceptual survey on wave optics - CSWO) was developed for assessing high school students'understanding of the basic wave optics concepts after instructions. This proposal shortly describes the process of the CSWO construction and its analysis. The results suggest that the CSWO is a reliable diagnostic instrument for administration in high schools and in some situations possibly also in universities, for introductory physics courses.

2 CSWO construction, methodology, and analysis

Semi-structured demonstration interviews with Croatian high schoolers (N=27) about the above-mentioned topics after their regular school instructions preceded the process of the CSWO construction. Using the findings from the interviews and other PER studies, CSWO learning outcomes were formulated following the initial set of items that probed these outcomes (i.e., some observed students'difficulties were used for formulating distracters).

The entire process of the CSWO construction included developing and testing six versions of the instrument and each version was analysed using the Rasch model. Altogether, 61 items and 759 students (of which were 145 university students) were tested. The sixth version of the CSWO was administered in high schools (N=224) during the school year 2019/20 right after their regular instruction on wave optics which takes about 4-5 weeks, with two or three 45-minute lessons per week. Rasch analysis of each version was done using Winsteps Rasch software and main measures of the instrument were obtained (e.g., item difficulty, item and person reliability, Cronbach alpha, infit and outfit measures⋯). The analysis of the CSWO's final version yielded a final form of the instrument with 26 items.

3 Results and analysis

The analysis shows good targeting of the test on the sample and good distribution of item difficulties. The Rasch person reliability index is 0.78 (similar to Cronbach alpha measure, 0.77), which is an acceptable value for a diagnostic instrument. The item reliability is 0.97. Both reliability measures are indicating satisfactory degree of replicability. The theoretical construct of the CSWO seems to be empirically confirmed and shows an increase of mean difficulty with increasing cognitive complexity of the items. In general, the chosen items seem to have succeeded in producing an adequately coherent unidimensional construct from the Rasch model perspective, with good validity and reliability.

4 Conclusion

The analysis showed that the CSWO can be used as a post-test for high school students and that the instrument shows good structure and functioning. The results of the CSWO tested on Croatian high school students suggest that the most difficult aspect was forming explanations and applying knowledge to real-life phenomena. This points to the students'lack of good models of basic wave optics phenomena, since they resorted to explaining them by combining many fragments of knowledge and chose the explanations that are consistent with the previously identified difficulties in PER.

Acknowledgements

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Primary authors: JELICIC, Katarina (Faculty of Science, University of Zagreb, Croatia); MATEJAK CVENIC, Karolina (Department of Physics, Faculty of Science, University of Zagreb); PLANINIC, Maja (Department of Physics, Faculty of Science, University of Zagreb); IVANJEK, Lana (Faculty of Physics, Physics Education Research, Technische Universität Dresden); SUSAC, Ana (Department of Applied Physics, Faculty of Electrical Engineering and Computing, University of Zagreb); HOPF, Martin (University of Vienna, Austrian Educational Competence Centre Physics)

Presenter: JELICIC, Katarina (Faculty of Science, University of Zagreb, Croatia)

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