Does inquiry-based teaching make a difference? Results of the research project on wave optics (INVESTIGATE)

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Abstract. The results of the project, comparing the effectiveness of inquiry-based vs. lecture-based teaching of wave optics, will be presented. An inquiry-based teaching sequence, spanning eight 45-minute sessions, was designed and implemented. The sequence incorporates four investigative student experiments exploring interference, diffraction, and polarization of light, complemented by teacher demonstration experiments. The teaching sequence was implemented in six Croatian secondary school classes and compared with traditional lecture-based instruction in six control group classes from the same schools. Results of the Conceptual Survey on Wave Optics indicate that the experimental group outperformed the control group in four out of five conceptual areas.

Introduction

Wave optics is a challenging topic for students, both at secondary school, as well as university level [1-4]. The most common student difficulties with interference and diffraction include not distinguishing between geometrical and wave optics and when to apply which model, treating every slit as a single point source of light, not understanding the role of path length difference in interference conditions, having trouble expressing distances in terms of wavelengths, and not distinguishing between different wave optics patterns [1, 2, 4, 5], Common difficulties regarding polarization of light were confusing the direction of oscillation of the electric field with the direction of light propagation and confusing a polarizer with a slit or an optical grating [1, 3].

Inquiry-based teaching represents an educational approach characterized by active engagement and student-centred exploration. The focus is on posing questions and problems, encouraging students to investigate and seek solutions through their own observations and research. This research specifically focuses on guided inquiry, a pedagogical framework wherein the teacher initiates the research question but encourages students to conduct independent investigations and to arrive to their own conclusions, providing the necessary support where needed.

Research question

The goal of this study was to create an inquiry-based teaching sequence on wave optics and to evaluate its effectiveness compared to traditional lecture-based teaching. The primary research question examined the impact of this inquiry-based teaching sequence on students' conceptual understanding of wave optics, compared to traditional teaching. Furthermore, the study aimed to identify the specific aspects of students' understanding of wave optics that exhibited the most improvement with the new teaching sequence.

Research design and methods

To address the research questions, a five-year research project named INVESTIGATE, was conducted. As a first step, qualitative research was conducted to explore high school

students' difficulties with wave optics [3, 4], leading to the development and validation of a diagnostic tool called the Conceptual Survey on Wave Optics (CSWO) [5]. Subsequently, a new inquiry-based teaching sequence was developed and suitable experimental equipment was selected and purchased. Participating teachers initially taught their classes with traditional lecture-based methods, then received training on the new approach and materials, and subsequently implemented the new teaching sequence with the next generation of their classes. Both the control and the experimental group were post-tested using the CSWO.

The teaching sequence spanned eight teaching periods, which is the typical amount of time allocated to wave optics instruction in secondary school physics in Croatia. The covered topics included double-slit interference, optical grating interference, single-slit diffraction, and polarization of light. The teaching sequence was designed according to the inquiry-based teaching principles. Students were engaged with scientific questions, conducting observations and describing the phenomena and their typical patterns. They were also encouraged to design and conduct investigative experiments, test hypotheses and to formulate and justify the explanations. The control and experimental group included 127 and 130 students respectively on the CSWO testing. These students were in the final year of secondary school, aged 18-19 years. Data was analyzed first with dichotomous and subsequently with partial credit Rasch model, and the CSWO posttest results for the control and experimental group were compared.

Results and conclusion

The experimental group taught by the new inquiry-based teaching sequence outperformed the control group which was taught traditionally. Students showed overall significantly better conceptual understanding, as measured by the CSWO. The Mann Whitney U test for the CSWO Rasch scores showed that the difference between the results of the control and experimental group on the CSWO test was statistically very significant ($U = 4536.5$, $p < 0.0001$). The better understanding in the experimental group, compared to the control group, was found in almost all aspects of wave optics understanding probed by the CSWO. The results of the project suggest that the inquiry-based teaching may promote students' conceptual understanding, but also that teachers need a lot of support in transitioning from lecture-based to inquiry-based teaching.

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