

Development and validation of the ray optics in converging lenses concept inventory

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✉ (Received 23 May 2022; accepted 7 September 2022; published 9 November 2022)

Optics is a core field in the curricula of secondary physics education. In this study, we present the development and validation of a test instrument in the field of optics, the ray optics in converging lenses concept inventory (ROC-CI). It was developed for and validated with middle school students, but can also be adapted for the use in higher levels of physics education. The ROC-CI can be used as a formative or a summative assessment of students' conceptual understanding of image formation by converging lenses, assessing the following: (i) the overall understanding of fundamental concepts related to converging lenses, (ii) the understanding of specific concepts, and (iii) students' propensity for difficulties within this topic. The initial ROC-CI consists of 16 multiple-choice items; however, one item was removed based on various quality checks. We validated the ROC-CI thoroughly with distractor analyses, classical test theory, item response theory, structural analyses, and analyses of students' total scores at different measurement points as quantitative approaches, as well as student interviews and an expert survey as qualitative approaches. The quantitative analyses are mostly based on a dataset of $N = 318$ middle school students who took the ROC-CI as a post-test. The student interviews were conducted with seven middle school students after they were taught the concepts of converging lenses. The expert survey included five experts who evaluated both individual items and the test as a whole. The analyses showed good to excellent results for the test instrument, corroborating the 15-item ROC-CI's validity and its compliance with the three foci outlined above.

DOI: 10.1103/PhysRevPhysEducRes.18.020131

I. INTRODUCTION

Optics is one of the core fields in physics [1–3] and, as such, it is universally represented in the curricula of secondary physics education across the world (e.g., in K–12 education [4]). One fundamental topic in optics education is the learning of concepts regarding the refraction of light by a converging lens and how images can be formed using a lens. This phenomenon of an illuminated object being refracted by a lens and projected on a screen is depicted in Fig. 1.

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Conceptual understanding is a fundamental aim of science education [4–6]. It can be described as relational knowledge about the key concepts of a domain and the interrelations among these concepts, including the understanding of relations between observable phenomena and the underlying abstract and invisible principles [7,8].

In this article, we introduce a test instrument that can be used to assess middle school students' conceptual understanding of image formation by a converging lens. This instrument is called the ray optics in converging lenses concept inventory (ROC-CI). A concept inventory (CI) contains conceptual ideas and common students' difficulties in the single items and is easily usable due to its multiple-choice item format. In this paper, we describe the development and validation process of the instrument. We validated the ROC-CI thoroughly with multiple complementary approaches, namely, quantitative analyses including distractor analyses, classical test theory, item response theory, structural analyses, and analyses of students' total

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