

Assessing student written problem solutions: A problem-solving rubric with application to introductory physics

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Problem solving is a complex process valuable in everyday life and crucial for learning in the STEM fields. To support the development of problem-solving skills it is important for researchers and curriculum developers to have practical tools that can measure the difference between novice and expert problem-solving performance in authentic classroom work. It is also useful if such tools can be employed by instructors to guide their pedagogy. We describe the design, development, and testing of a simple rubric to assess written solutions to problems given in undergraduate introductory physics courses. In particular, we present evidence for the validity, reliability, and utility of the instrument. The rubric identifies five general problem-solving processes and defines the criteria to attain a score in each: organizing problem information into a Useful Description, selecting appropriate principles (Physics Approach), applying those principles to the specific conditions in the problem (Specific Application of Physics), using Mathematical Procedures appropriately, and displaying evidence of an organized reasoning pattern (Logical Progression).

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I. INTRODUCTION

Solving complex, nonroutine problems has been recognized as essential for all citizens, especially those in technical fields [1,2]. Because physics courses serve as a foundation for disciplines both inside and outside of STEM, they are an ideal venue for teaching problem solving.

It is common for physics instructors to use problem solving as a mechanism for teaching physics content and assessing if that content has been learned. In addition, instructors often have a goal of helping students construct physics knowledge [3] or introducing students to the culture of science [4], both of which also require a generalized problem-solving framework. Indeed, physics education researchers have developed different types of problems [5–8], curricular add-ons [9], intelligent tutoring systems [10], and entire curricula [11,12] designed to scaffold the learning of problem solving. However, one significant barrier to the development and dissemination of

such materials has been the lack of a validated, standard, general, and easy-to-use assessment tool for measuring the quality of students' problem solving.

In this paper, we describe the development and testing of a simple rubric for assessing students' problem solving based on their written problem solutions. In Sec. II, we first discuss the research on problem solving and its assessment on which our work is based. Section III describes the design of the rubric, including its categories and scoring criteria and how it is related to previous work. Section IV presents evidence for the validity and reliability of the instrument, using a framework from the *Standards for Educational and Psychological Testing* [13] and Messick [14]. Finally, we discuss some applications of the problem-solving rubric in Sec. V. More detail on the development of the rubric and many of the studies described in this paper can be found in Ref. [15].

II. BACKGROUND

A. Research on expert and novice problem solving

The process of problem solving occurs when a person needs to resolve a situation where they do not know a specific set of actions they can use to reach that resolution [16]. For example, Martinez [17] summarizes the cognitive science definition of problem solving as “the process of moving

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