Boosting Problem-Solving Skills in Physics Classes: Conceptual Understanding Through Context-Rich Problems

Diana Domenichini (1), Gualtiero Fantoni (2), Filippo Chiarello (2), Marilù Chiofalo (3)

(1) Department of Computer Science, University of Pisa, Italy
(2) Department of Engineering, University of Pisa, Italy
(3) Department of Physics, University of Pisa and INFN, Italy

Abstract. Physics Education Research (PER) seeks to address students' struggles with problem-solving in physics by introducing innovative educational methods. This study proposes using a conceptual problem-solving (CPS) framework to tackle context-rich problems (CRPs) in physics courses of life science disciplines. CRPs have an alternative and misleading narrative, and the CPS framework prioritizes qualitative understanding over quantitative solutions. We aim to investigate university's students' perceptions and outcomes, focusing on gender and knowledge transfer abilities.

Introduction

Problem-solving skills are vital in physics education and are anticipated to be crucial for the future [1]. However, there remains a significant disparity between the problem-solving skills taught in educational settings and those required in real-world scenarios.

In professional and everyday contexts, problems are often ill-structured, with limited constraints, diverse evaluation criteria, and too vague objectives [2]. Conversely, standard classroom problems typically oversimplify, focusing narrowly on specific physics concepts, often requiring the rote application of formulas (mean-end analysis), which fails to foster deep conceptual understanding or robust problem-solving abilities [3].

To address this disparity, PER has proposed various approaches [3]. Our focus in this work centers on Context-Rich Problems (CRP) [4] and Conceptual Problem-Solving (CPS) [5]. CRPs are brief narratives set in real or imaginary contexts that require the calculation of a specific quantity related to objects or events [4]. CRPs are complex and ill-structured problems. CRPs, being non-coded descriptions of situations, are more resembling to experimental work, allowing students to develop their experimental skills using only pen and paper. CPS framework is an instructional approach that asks students to identify concepts and principles, justify their use, and plan their solution in writing before solving a problem [6]. It prioritizes qualitative solutions and conceptual understanding.

We require an instructional methodology to aid students to handle complex problems and to comprehend physics concepts and laws in everyday situations.

Research Questions

We propose an integrated CRP-CPS educational approach focused on solving CRPs using CPS framework. Our study addresses three key research questions (RQs):

1. Does solve CRPs increase students' motivation? If so, is it due to the challenges posed by these problems or their inherent interest?
2. How do students approach and solve CRPs? Does it change among different genders?
3. Do students perceive differences between pairs of problems that require the same problem-solving method? Additionally, do their strategies vary among different problems? If so, which strategies are more effective and efficient?

Methodology

As a case study, we take into consideration the Introductory Physics course at Pharmaceutical Chemistry and Technology course degree at the University of Pisa. Unlike engineering or pure science tracks, which heavily emphasize mathematics and physics, the curriculum for life science disciplines is tailored to accommodate the reduced formal-language literacy of the students enrolled in these subjects. These physics courses aim to develop critical and scientific thinking and problem-solving skills for future scaffolding and careers, rather than focusing on extended physics contents and complicated math.

The considered introductory physics course is structured with an initial qualitative overview of physical concepts, starting with class demos and followed by formal instruction [6]. During lectures and, additionally, in recitation hours, students are interactively engaged in solving case exercises categorized by type and implemented in the form of CRPs, discussed in groups and solved in a CPS framework. Standard problems using the same procedure as the given CRP are then presented and solved. The exam is a written test, structured in a way to respond to the three RQs, respectively:

1. Choose between CRPs and standard problems, and to justify their choice.
2. Solve the chosen problems.
3. Identify similarities in solving procedures for additional problems presented.

The didactic experiment is being conducted in the second semester of the academic year 2023/2024, during which the data are being taken and analyzed. The detailed result of the analysis will be presented at the 4th WCPE conference.

Conclusions and perspectives

The original aspect of this research is combining CRPs and CPS framework, and examine if they enhance knowledge transfer between problems. The goal is to address the disparity between academic learning and practical problem-solving needs. By analyzing student test exams, we address RQs, particularly focusing on gender differences and knowledge transfer abilities. Our study highlights the importance of critical thinking in real-life problem-solving within a life science curriculum. CRTs simulate real-world scenarios, making physics more experiential. Our work opens up the way for new effective teaching environments and the creation of CRP texts with CPS integration.

References

[1] OECD, *The Future of education and skills*. Paris: OECD Publishing, 2018.

[2] D. H. Jonassen, Toward a design theory of problem solving, *Educational Technology Research and Development* **48**(4) (2000) 63–85.

[3] A. Maries and C. Singh, Helping students become proficient problem solvers Part I: A brief review, *Education Sciences* **13**(2) (2023)156.

[4] P. Heller, R. Keith, S. Anderson, Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving, *American Journal of Physics,* **60**(7) (1992) 627–636.

[5] J. P. Mestre, J. L. Docktor, N. E. Strand, B. H. Ross, (2011). Conceptual Problem Solving in Physics. In J. P. Mestre & B. H. Ross (Eds.), *Psychology of Learning and Motivation* **55** (2011) 269-298 Academic Press.

[6] M. Chiofalo, The Physics of Everyday Life Toolbox for Basic Physics Courses, *Communications in Computer and Information Science* **1542** (2022). Springer, Cham.