Teaching Critical Thinking in the physics classroom: High-school students think about antimatter

Farahnaz SADIDI, Gesche POSPIECH

Technische Universität Dresden, Faculty of Physics, Chair of Didactics of Physics, 01062 Dresden, Germany

Abstract. In this study, we present our content-specific instructional design for promoting students' critical-thinking (CT) skills. The target group comprises German high-school students grade 11 and 12. The specific topic of learning modules is antimatter. To design explicit CT instruction, we combined the model of "First Principles of Instruction" with our domain-specific interpretation of Halpern's domain-general definition of CT skills. To develop and optimize our instructional design, we use a Design-Research cycle.

1 Introduction

It is a goal of education researchers and teachers to design a learning environment for students so they can practice critical thinking for everyday life.

The most common way to think about critical thinking (CT) is to define various thinking strategies [1] (section 3). It is also important to distinguish between domain-general CT skills, which require knowledge of everyday life [2] and domain-specific CT skills, which require content-specific expertise [3], e.g. in the domain of particle physics.

There has been some research on designing a content-specific instruction, for example in electricity and magnetism [4] where CT skills are trained. There, the model of "First Principles of Instruction" [5] was applied to design a content-specific instruction. Here, it was our goal to design a course about antimatter, a modern topic emerging in physics education. Accordingly, we have posed the following research question: **How can we design a content-specific instruction, based on the "First Principles of Instruction" and Halpern's definition of critical thinking (CT)?**

2 Method

In designing a content-specific instruction, the model of "First Principles of Instruction" was combined with domain-specific CT instruction, *cf.* [6]. To fulfill the central principle of problem-centeredness, a problem was identified which related both to particle physics, and students' everyday lives, and required CT skills. After brainstorming and discussion with particle physicists from IKTP (Institute for Nuclear and Particle Physics), the fiction movie "Angels & Demons" (2009) was chosen because it features an antimatter bomb. To define domain-specific CT skills, Halpern's domain-general definition [1] was applied to the domain of particle physics. Furthermore, explicit teaching of CT skills was done by defining and illustrating these skills within the first course session. The preliminary course design corresponds to the first stage of a Design-Research cycle [7].

3 Preliminary Course Design

Table 1 and 2 refer to some examples of planned student activities.

Table 1 Applying the “First Principles of Instruction” to the topic of antimatter

Principle	**Examples of student activities**
Problem-Centered	Judge reality of some scenes of movie “Angels & Demons” (antimatter bomb)
Activation	Review prior knowledge (e.g. conservation laws)
Demonstration	Focus on purpose, main questions and missing information while doing research
Application	Explain and discuss principle of Positron Emission Tomography
Integration	Resolve ambiguity of equation $E= mc^2$

Table 2 Applying Halpern’s definition of CT (Critical Thinking) to the topic of antimatter

CT Skill	**Examples of student activities**
Reasoning	Distinguish between mass and matter
Argument Analysis	Compare two alternative atomic models based on Rutherford’s experimental results
Hypothesis Testing	Check their own proposal of antimatter trap against existing systems
Likelihood and Uncertainty Analysis	Provide alternative interpretations of Anderson’s cloud chamber image
Decision Making and Problem Solving	Design set-up to support notion of quarks, in analogy to Rutherford’s experiment

4 Discussion

Here we introduced our instructional design for training Critical Thinking skills within the context of antimatter. Teachers can use the proposed activities. However, the course still needs to be tested and refined.

So far, we have implemented our instructional design as a two-day workshop with 8 physics teacher students. Furthermore, we have run the first pilot study as a four-day workshop at the university with 4 high-school students (grades 11 and 12). Based on the feedback, we are optimizing our course design.

In future work, we will present a test to determine the extent to which students have achieved the learning goals.

References

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