How History and Philosophy of Science Can Inform Teaching and Learning of General Relativity in Upper Secondary School

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Science educators have to move beyond traditional content-focused instruction to teach concepts of Einsteinian physics. This work presents a design-based research project that introduced general relativity (GR) to upper secondary school students in Norway. The educational approach invited students to explore the historical development and philosophical aspects of GR within a digital learning environment. Results based on focus group interviews show that students were particularly motivated by such an approach. We argue that employing history and philosophy of science in the service of physics education can serve as a successful approach to making GR more accessible to young learners.

Keywords: Physics Education; History & Philosophy of Science; General Relativity

1. Context and Background

Few scientific discoveries have had a bigger impact on our understanding of the Universe than general relativity (GR). Einsteins revolutionary theory of gravity did not only herald a new scientific age, but fostered a new interest in the philosophy of space and time as well. Yet, despite its scientific, philosophical, and technological importance, GR is lacking from most school curricula today. This work presents a design-based research project that introduced GR to upper secondary school students in Norway. The educational approach invited students to explore the historical development and philosophical aspects of GR within a digital learning environment. Research suggests that history and philosophy of science can be fruitful in teaching and learning of physics[3,5]. We were particularly interested to see how such approaches might foster understanding of and motivation for GR.

2. Theoretical Framework and Methodology

We cast the development of a digital learning environment in GR into the framework of design-based research to bridge the gap between educational research and the physics classroom.[1] Our goal was to find workable solutions to make GR accessible at upper secondary level. Starting from the assumption that learning becomes visible in social interaction[4,6] and in line with the iterative nature of the design-based research methodology, we conducted two rounds of field studies, one in spring 2016 and one in spring 2017. In total, eleven upper secondary physics classes in five Norwegian schools participated. To gain insight into students experiences, we conducted seven semi-structured focus group interviews with 5 to 8 participants per group and 46 students (18-19 years) in total. The teachers chose the students to allow for a balance of gender and to include both stronger and weaker students. We based the interviews on an interview guide focusing on the design of the learning activities, use of history and philosophy, and students challenges and motivation. We then transcribed the interviews and analysed them using thematic analysis.[2]

3. Results and Design Examples

Preliminary results of the analysis of the focus group interviews show that students approved of a historic and philosophic perspective on learning GR:

Interviewer: *So you mentioned this historic approach. [...] What do the others think about it?*
Student 1: *I think it was good.*
Student 2: *(mumbling) as theoretical physicist: Oh, it's like that. But that it became clear why it is like that. And it is good that they explained how they ended up there, why it is actually like that.*
Student 3: *Why there is disagreement. I think this was interesting.*
Student 4: *Yes, it gets maybe easier to make connections. Or the theories up to now, if you get, somehow, you know a bit about the history and what happened before. And you get, somehow, something you think - because you think the history is fascinating - [something that] helps there, you make better connections this way than just getting the theory or the formula straight into your face without any evidence for understanding why it came out like that.*
Student 5: *And if you also learn about how they reached this [understanding], then it can be easier to understand why it actually works.*

Interviewer: *So do you feel you have learned something?*
Student: *Yes, I think it was really nice that you got, like, the perspective of recent scientists who made their new discoveries so that you get a bit more recent perspectives. Because it is a bit easy to think that physics is just somehow in the book at school.*

Students felt generally motivated by an approach relying on history and philosophy of science because

(1) it showed that Einstein was a real person who struggled to find a new theory of gravity,
(2) it helped them to connect GR to their knowledge of classical physics by following the historic development of GR,
(3) it presented physics as part of our cultural heritage and showed its social relevance, and
(4) it presented physics as a modern field that has more to offer than just out-dated textbook knowledge.

The findings from the focus groups informed revisions of the learning environment and led to a series of activities that draw on historical events and philosophical questions (Figures 1-4). The learning environment *General Relativity* is accessible at the Norwegian learning platform Viten: www.viten.no/relativity

Fig. 1. The learning environment contrasts the first experimental confirmation of GR to the recent breakthrough in gravitational wave astronomy. Students can move between newspaper headlines from 1919 and 2016.

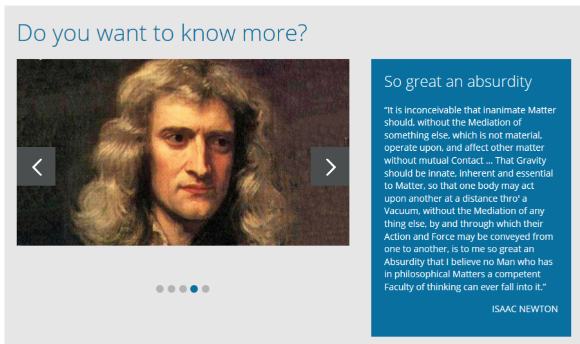

Fig. 2. Newton felt uncomfortable with the mysterious force of gravity that exhibits the principle of action at a distance. In a letter to a colleague, Newton called the gravitational force a 'great absurdity'.

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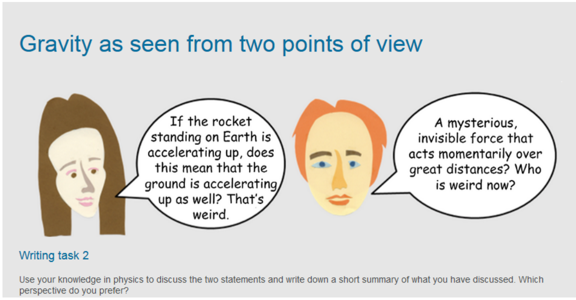

Fig. 3. In a discussion task, students are asked to discuss the epistemological implications of Einstein's and Newton's interpretation of gravity.

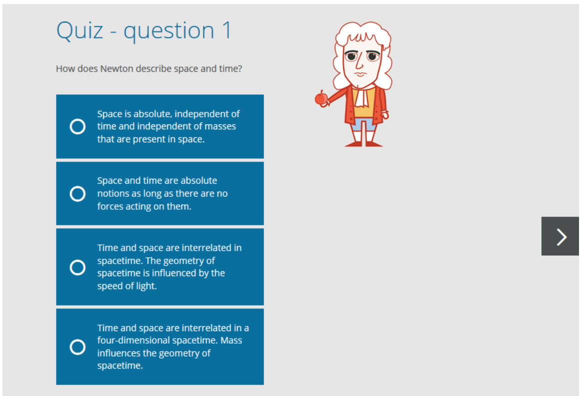

Fig. 4. In a quiz, students can probe their understanding of space and time according to Einsteinian and Newtonian perspectives.

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