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

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Abstract. 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.

1 Context and Background

Few scientific discoveries have had a bigger impact on our understanding of the universe than general relativity (GR). Einstein's revolutionary theory of gravity did not only herald a new scientific and technological age, but fostered a new peak time 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, possibly because of its abstract nature. This work presents a design-based research project that introduced GR to final year 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. While physics education research suggests that history and philosophy of science can be fruitful in teaching and learning of classical physics and even special relativity (1,2), we were interested to see how approaches that emphasize historical, philosophical, and sociocultural aspects might foster understanding 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 (3) to bridge the gap between educational research and the actual physics classroom. Thus, our goal was to find workable solutions to making GR accessible at upper secondary level. Starting from the assumption that learning becomes visible in social interaction (4,5) 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 with the learning environment, 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 (6).

3 Results and Conclusion

Preliminary results of the analysis of the focus group interviews show that students approved of a historic and philosophic perspective on learning GR. They felt generally motivated by such an approach 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:

Interviewer: *Are there parts of the learning environment you remember especially well?*
Student 1*: I think maybe the part with the letters* [fictional letters of Einstein that show his struggle with the mathematics of GR] *because it was, you got sort of into the same reasoning that made Einstein and his friend, I wonder (mumbling) […] eh, the same that got into the thoughts of them that resonate within me a bit as well. That you could use this knowledge in a somehow different way than to calculate.*

Moreover, the findings from the focus groups informed revisions of the learning environment[1] and led to a series of activities that draw on historical and philosophical events: The learning environment contrasts for example the first experimental confirmation of GR to the recent breakthrough in gravitational wave astronomy. Students get to explore the gravitational bending of light observed during the solar eclipse in 1919 and they can move between newspaper headlines from 1919 and 2016. In conclusion, 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 learners at upper secondary school level.

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[1] The learning environment is accessible at the Norwegian learning platform Viten: www.viten.no/relativity