Public lectures by scientists on contemporary physics topics: Characterizing explanations, instructional use, and a study of learning

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Abstract

The advances in physics which took place during the late twentieth century in areas such as cosmology, quantum physics, etc, could easily capture the interest of young people. Yet contemporary physics is absent from most high school curricula, as it is considered “unexplainable” to nonprofessional audiences. This dissertation examined how such advanced physics ideas are presented to the general public in exemplary public physics lectures, delivered by practicing scientists known as excellent public lecturers, and how these lectures can be utilized to present contemporary physics to physics teachers and high school students.

How can one explain deep, sophisticated and innovative scientific ideas to an audience that lacks sufficient prior knowledge? How can public physics lectures be utilized to enrich high school physics with contemporary topics? How can such lectures be integrated into high school teaching and professional development courses for in-service teachers? What is the meaning of 'learning' in such a context? These were the questions that motivated this research.

The study is divided into two parts. The first is a comparative study of seven exemplary public physics lectures, given by practicing physicists who are acknowledged to be excellent public lecturers. The study uses three different perspectives: the lecture (N=7), the lecturer (N=7), and the audience (80 high school physics teachers and 169 students). The second part is an instructional study that explores the utilization of public lectures for the instruction of contemporary physics in formal settings (high school and courses for in-service teachers). It involved 20 in-service teachers who took part in a professional development course (3 lectures), and 14 students from the Technion’s Pre Academic Education Center who took part in a learning

experiment (2 lectures). Both teachers and students studied contemporary physics topics while using public web-lectures, and specifically designed collaborative learning activities: guided note taking, active construction of the scientific arguments and reformulations of analogical inferences that the lectures present.

The research employed three complementary perspectives: (1) Content: characterizing the nature of the explanations and their crafting, (2) Learning: characterizing the learning processes and outcomes that are involved in naturalistic contexts (e.g. an audience listening to a popular lecture) and in formal learning contexts (in class, scaffolded by specifically designed tools), (3) Instruction: designing mediating activities and exploring how these lectures can be effectively used to incorporate contemporary physics into high school curricula and into professional development courses for science teachers.

Our findings suggest that exemplary public physics lectures, which are delivered by noted scientists, present content, structure and explanatory means that explicitly adhere to the lecturers' goals. Moreover, these goals are highly congruent with the audiences' expectations. The lecturers and the audiences both stated that a good public scientific lecture must successfully communicate state of the art scientific knowledge to the public, while inspiring interest in and appreciation of science. However the audiences emphasized the content while the lecturers stressed inspiring interest and excitement.

The results show that good public physics lectures share a common explanatory framework – the Translated Scientific Explanations (TSE). This framework consists of four clusters of explanatory elements: content, analogical approach, story, and knowledge organization. The study formulates this framework and derives a list of 12 design principles from it that can guide the crafting of new lectures. The explanatory framework explicates how the gap in the prerequisite prior knowledge is bridged. This explication can be used to assess existing lectures, and guide the design of mediating activities.

Although physics educators tend to dismiss the use of public physics lectures as an instructional resource, regarding the lectures as 'entertainment', this view is challenged by the findings of the instructional study. Our results show that when student- centered mediating activities accompanied such lectures, meaningful learning occurred. Nevertheless, the learning processes that took place and the outcomes were different from those documented in inquiry learning and problem solving sessions. We documented a complex growth in the declarative knowledge base, which was assessed through six dimensions of change: larger size, denser connectedness, increased consistency, greater complexity, higher level of abstraction, and shifted vantage point. We saw the realization of several understanding performances: explanations, justification, comparing and contrasting, and contextualization. However, exemplifications, applications, and generalizations were not observed. Learning was also evidenced in tests of long-term memory of scientific content, and transfer of the nature of science (NOS) aspects. Another indication of meaningful learning was the explicit use of prior scientific knowledge learned in school in the guided discussions that followed the lectures (correct and incorrect use). Furthermore, the learning outcomes were enhanced by the mediating learning activities, and did not depend on the lecture topic.

Thus we argue that contemporary physics topics can be integrated successfully into a traditional syllabus, using public physics lectures, and be appreciated by their learners. The findings also suggest that public scientific lectures can be used as a platform to present the scientific method (i.e. the nature of science - NOS), and as a context to train students in the craft of scientific argumentation. Theoretical and practical implications are discussed.