THE WAYS THE THEORY OF PHYSICS EDUCATION CAN EVOLVE

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Theory of physics education, as well as our Journal of Baltic Science Education, made a significant step over the last 20 years. Twenty years ago, formal physics education had a one-and-a-half century of development; JBSE was just an idea to be turned into the 1st issue in 2002. In this article, I would like to mention some of the great steps physics education made in the last decades and some open questions for the nearest future. I would like to apologize to the readers from the field of biology, chemistry or primary science education - unlike in my previous articles in this Journal (Demkanin, 2013; Demkanin, 2018), here I focus on physics education.

Some retrospective on physics and science education was done by Jong (2007); Yun (2020), and Girwidz et al. (2019). It is possible to divide the main research results of physics education from the last decades to three clusters. The main result cluster (Cluster A) can be grouped about the idea: in upper-secondary school, we could profitably think about a problem for weeks. Cluster B is related to the profitable use of digital technologies by students, and Cluster C is associated with the methodology of research in physics education. Let us try to present this idea on a concrete example.

One of the activities, I regularly use with my university students – future physics teachers is a complex activity with a filament lamp. As a result of physics education research (Cluster A), we know, that complex activities can be profitably used in physics education (diSessa, 1988; diSessa, 2017). In the last century, we usually used a filament lamp for presenting a non-linear Voltage-Current characteristic, as in Figure 1 bottom left. Students know that Ohms law usually applies to a metal wire. The filament of a lamp is a metal wire, so assumption about linear Current-Voltage dependence is relevant. The dependence of resistivity on temperature is also a standard high school topic, so we usually address the topic with our students. Inspired by ideas of Cluster A, we decided to go further, to the topic of black body radiation. The assumption that heat from the filament is transferred to the environment in the form of radiation could be justified at the secondary school level. Of course, from the measurement of the Current-Voltage characteristic of a bulb to inquiry of the radiation of a bulb, is a long way. Which complex problems are optimal for physics education? Which competencies are developed? Which and at what age level, by which methods? What are our goals, and why? What are other questions reasonable to solve in our research in Cluster A?

Development of the previous ideas about the filament lamp are firmly related to the results from Cluster B – use of digital technologies in physics education. Students can find information relevant to the radiation of hot object in their digital sources of information, but let us focus here not on general, but on subject-specific competences (Becker at al., 2020). Students can collect data of voltage and current for a bulb by voltage and current sensors. Having the data in digital form is a great advantage in contrast to getting the data with universal Voltmeter and Ammeter, filling a table in an exercise book.

Having a proper general plan of the data processing, the student can easily calculate power, resistance and even the temperature of the filament bulb. Having the hypothesis, that the filament transfers all the power to the surrounding by radiation (not by heat convention, negligibly by heat conduction), the student can use the formula for the rate, at which a hot object radiates, within the process of hypothesis formulation. The rate should be proportional to the fourth power of temperature. The coefficient of proportionality includes emissivity and surface area of the object. To verify the hypothesis, Students plot a graph of power vs the fourth power of temperature as in Figure 1 top left.

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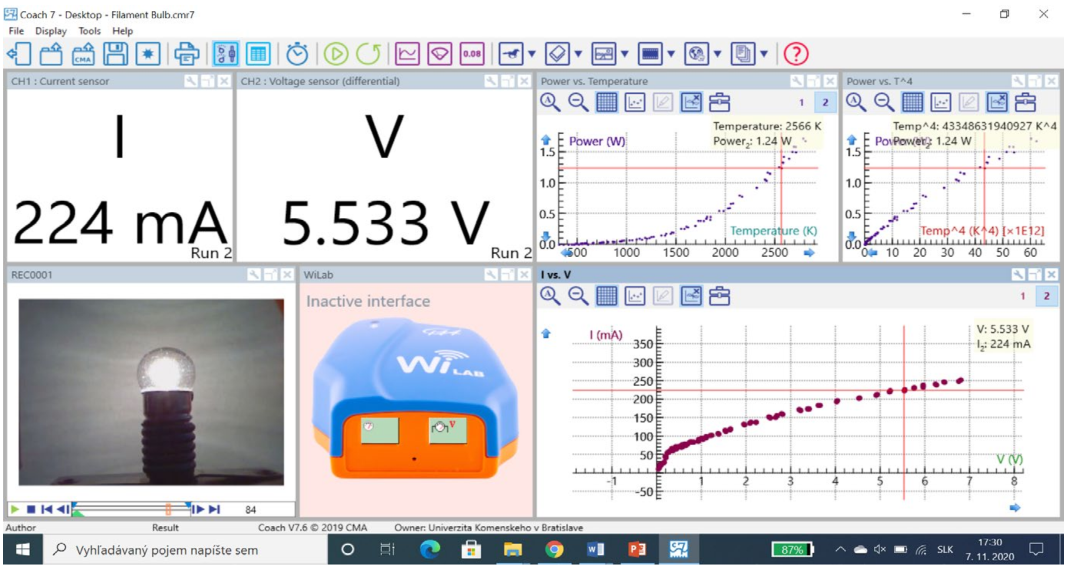
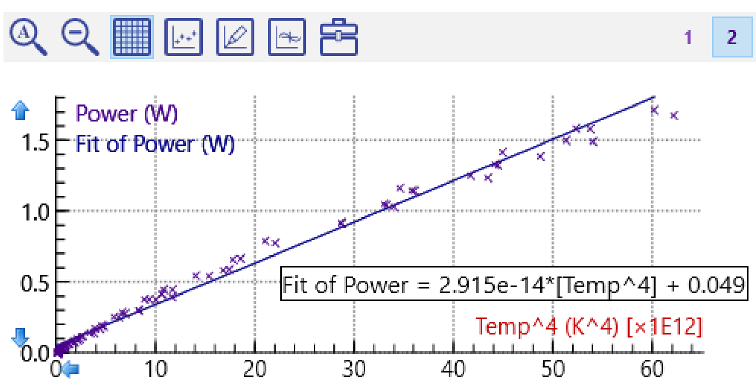
Figure 1
The screen of the activity with synchronized video, scanning measured and calculated values, in Coach 7



Moreover, the student can see that the graph could be, within the uncertainties, taken as a graph of proportionality (linear through zero), Figure 2. By comparison with the formula for the power of black-body radiation, the student can estimate the surface area of the filament.

Figure 2
Students try to find the diameter of a filament comparing the slope of the graph with the formula for black body radiation, in Coach 7



I usually provide students with the value of the length of the filament so that they can estimate the radius of the filament. Here again, is a general use of digital technologies; students can compare the surprisingly small radius calculated with the values available from web resources. The process from the Current-Voltage characteristic to the radius of the filament takes a long time; firstly, students are focused on measurement of electrical quantities, later focused on power, and at another time focused on the temperature dependence of resistivity of a metal. I found the activity useful also in a revision of formula for the surface area of cylinder, in non-standard context. Which competencies does a student need to be able to use digital technologies in a meaningful way? How can we develop these competencies? A lot has been done in this area by Ellermeijer and Tran, (2019) and by Li et al. (2020).

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After this example, let us go to the third group of topics, in this article referred to as Cluster C. Here we grouped research results on the methods used for our research. Theory of Physics Education could be (and it is) a science. Many researchers, within the long history of physics education, examined and discussed the methods of research. I would like to focus our attention on the methods related to modelling. Modelling student thinking is a concept used by many researchers (Harlen, 2006; diSessa, 2014; Sawyer, 2015). Redish (2004) used the word modelling even in the title of his contribution to the conference of Physicists: A theoretical framework for physics education research: Modelling student thinking. As researchers in physics education, we can see some analogy between modelling of reality within physics education (e.g. in Coach 7) and modelling of cognitive processes. Unfortunately, we still are not able to use computers in modelling cognitive processes, but artificial intelligence offers interesting solutions. Also, physics education needs in-depth research on the topics of its goals and aims, on societal issues. That is entirely different – here we often do not have enough information even to state a hypothesis. The grounded theory methodology by Charmaz (2014) is often optimal.

Which ways can the Theory of Physics Education evolve? Surely, it will keep up with the new knowledge gained by the research in Physics. In 2017, two neutron stars were observed to merge (Abott et al., 2017), and in 2020 this accrued in the final exam of the International Baccalaureate Diploma Programme (IBO, 2020). As well we can be sure the Theory of Physics Education will keep up with research on humanities. We already know a lot about the human personality (Cloninger, 2004; Zwir, 2019), ways of thinking (diSessa, 2017), abductive reasoning (Magnani, 2017). Both ways will determine the development in each of the clusters: teaching-learning; digital technology use and the methods of research. In the end, I would like to mention an example of Physics textbook for students, based on the results of research, based on a well-designed, evidence-based curriculum, MYP Physics: a concept based approach (Heathcote, 2018).

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