HEATING A CURRENT-CARRYING WIRE WITH ICE: AN ACTIVE-LEARNING SEQUENCE WITH A SURPRISE

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1 INTRODUCTION

The education system is a key role player in reaching out to deliver knowledge, awareness and general approaches in the mindset of the people. Bosnia and Herzegovina (BiH) is a country in transition, and its fast social and economic changes require educational reform. BiH education sector is in process of reform and has a potential and strong interest for development of curricula. Curricula reform at all levels of educational system in BiH is an ongoing process. Changes of teaching and learning methodology are required in education for physics teachers who need to be better prepared for such changes. How physics might be taught, and what mechanisms need to be applied for making reform faster and more effective? Administration at almost 13 levels in the state did not yet start to organize activities regarding physics teachers' education needed for their preparation to gain abilities in enhancing their active role in the reform. Physical Society in Bosnia and Herzegovina collaborating with Ministry of Education at Sarajevo County level recently organized a seminar consisting of series lecturers and workshops on active learning. That seminar was leaded by two experts in the field of physics teachers' education who came from Mexico and Slovenia. Physics teachers from secondary schools, university physics educators and senior physics students from Sarajevo County attended that Seminar. In the workshop which was a part of the Seminar students met a useful sequence based on surprise outcomes of the experiment for the first time.

The experiment which was realized is one surprising simple experiment known as Sir Humphry Davy's experiment. Sir Humphry Davy (1778-1829) is famous for showing that two ice cubes can be melted by friction. Less known is his demonstration that is possible to increase the glow of a barely glowing, current-carrying wire by cooling one of its parts by ice. Its strong visual appeal that is based on use of contrasts was integrated in an active learning sequence about observable effects of electric current.

The sequence was tested with 19 girls (13 high school students and 6 students at the University of Sarajevo). In this report the rationale behind the learning sequence and outcomes are described and commented. The girls were also asked to compare this learning experience with those they have from regular physics classes. Some of their observations and conclusions are briefly presented.

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2 ACTIVE LEARNING SEQUENCE APPLIED IN THE WORKSHOP

When workshop participants ask "why is active learning needed" the workshop leaders explain that significant physics learning means constructing conceptual knowledge which can be used in multiple physical situations, especially in those different from one in which the learning took place. If students are passive listeners and observers (even of excellent physics presenters), no significant physics learning occurs. Students should use their previous conceptual and factual knowledge to solve novel tasks. Students were asked to go throughout three steps: to *predict* (what will happen), to o*bserve* (what happened), and to *explain* (eventual differences between their prediction and observation) [1]. This sequence was especially effective because of its surprising difference between the prediction and the observation. Students needed to revise their basic assumptions and reasoning patterns about the physical phenomenon in questions.

The introduced Davy's experiment covers some topics related to electromagnetic phenomena. Davy had stretched a wire between two terminals about a meter apart and passed current through it, so that the wire was barely glowing. Than he rubbed a piece of ice along the central portion of the wire, about 30 cm long. As the wire cooled down the two portions on either side of the cooled part begun to glow red hot. In this workshop version of the experiment, an experimental device was used as presented on the Fig. 1. It consists of the copper wire around 2 m long and with a 0,5 mm diameter. One half of the wire was colled by an ice cube.

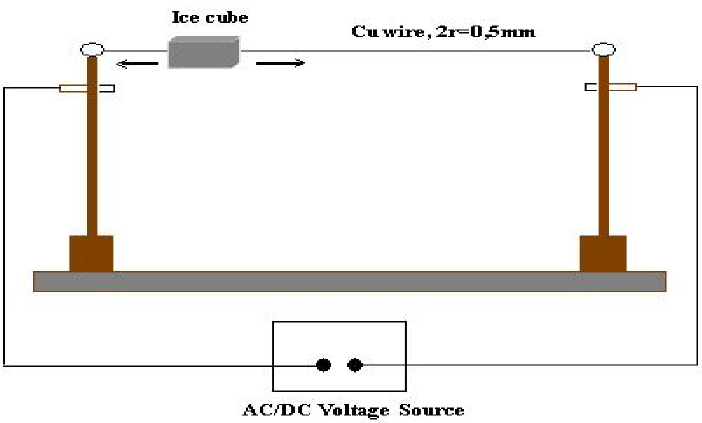


Figure 1 Davy's experiment applied in the workshop.

3 WORKSHOP STRUCTURE AND OUTCOMES

Girls received workshop working sheets prepared by instructors written in English and were guided by instructors throughout workshop activities.

In all, 19 students were divided into 6 groups according to their education level. One group had 3 members who did not learn anything about related topic. There were 3 groups with 3-4 members at high school level who learned about realized topic in their physics classes. University students worked as 2 different groups. In the first group there were 3 freshmen level girls (only one with physics major), whereas the second group had 3 senior physics students.

The questions given on the working sheets are presented in Table 1. It is seen what workshop participants were asked within the twelve active learning steps sequence, and how instructors aimed to link such questions and tasks crossing three tasks: to predict, to observe, and to explain. The students' answers to questions 1 and 2 and corresponding numbers of occurrence are presented in Table 2.

Beside Davy's experiment the instructors included one helping problem in order to guide girls toward the correct prediction by activating their existing knowledge about electric circuits. They used a simple circuit with two resistors and a battery to demonstrate how voltage changes. They also correctly predicted what would happen if one resistor is replaced with one with smaller resistance.

When asked about the glow of the uncooled part of the wire 7 students predicted that glow will stay the same, and 11 students thought the glow will decrease. Only one student "predicted" that the glow will increase. However, it was probably done by chance because her verbalization and arguments do not support that prediction. Some students didn't note, due to the fact that the questions were in English, that they should consider what would happen to the glow of the uncooled part. It should be noted that most of these students already learned about the temperature dependece of resisitivity of metals in school (only 2 of them did not learn about it)! The main results: predicting the glow of the uncooled part of wire was consistent with their previous predictions. The students, who predicted that the *cooled part* should decrease its glow, used mainly factual knowledge "cooler wire glows less" instead of expected reasoning "less resistance – less voltage drop – less glowing". The students, who predicted that the *uncooled part* should decrease its glow, based their prediction on the idea of "coldness propagation". Some even said that the uncooled part might have the same glow only if the wire were long enough. The students who predicted that the glow will not change used this reasoning pattern: the glow depends on current intensity – the ice can not affect current intensity – so, the glow stays the same.

After observing the experimental demonstration of the glow change of the uncooled part of the wire 11 students described the glow increase of the uncooled part of the wire correctly. Some of them could not hide their surprise:
"I was surprised because I didn't know that the second end will be brighter than before", "The result of the experiment surprised me", "I didn't expect the increase of the temperature on the second end", "The experiment surprised me", "It is just opposite than what I thought", "The remaining part of the wire was glowing stronger than until then and looked very hot", "We realized that the glow was stronger what was opposite to our expectations". Only one student reached the

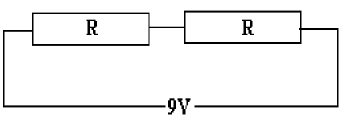
expected explanative model: smaller temperature leads to smaller resistance and smaller voltage drop in cooled part. It implies bigger voltage drop and bigger glow in the uncooled part.

There are two interesting alternative explanative models including two law of conservation: *conservation of current* (by cooling, current decreases, the "sufficient" of current there goes to the uncooled part, causing increase of current in it which leads to a bigger glow), and *conservation of heat* (the heat from cooled part goes to the uncooled part, making it hotter which leads to a bigger glow).

Table 1 Different types of answers to questions 1 and 2 and corresponding numbers of occurrence.

<table>
<tr><th>No.</th><th>Question/task</th><th>Aim</th></tr>
<tr><td>1.</td><td>Thin wire is connected to the power supply, as shown by the instructor. Give suggestions for observable effects that would convince us about the existence of the current in the wire.</td><td rowspan="2">By these two questions we wanted to activate the factual and predictive knowledge students have about the observable effects which indicate the existence of the current in the wire.</td></tr>
<tr><td>2.</td><td>Suppose that the voltage of the power supply is increased. Predict how the increase in voltage would change the effect, which you suggested in the previous question.</td></tr>
<tr><td>3.</td><td>Before we go on, let's think about the following problem:

A) Two equal resistors in series are connected to the 9 V battery (which has negligible internal resistance) as shown in Figure. What is the voltage drop across each resistor?

B) Now, one resistor is replaced with new one, which has smaller resistance. How will this change the voltage drop across the remaining resistor?
</td><td>Here we wanted to activate the factual and predictive knowledge students have about a simple electric circuit consisting of a battery and two resistors.
As will be seen later, the reasoning used to predict the change in voltage drops in this circuit can be used to predict correctly what will happen in the experiment devised by Davy. In other words, we were interested in checking if students are able to *transfer* their knowledge from an abstract to a concrete physical situation.</td></tr>
<tr><td colspan="3">*Addressing the students:* Now back to the thin wire. The following experiment will be performed and you will be asked several questions about it. Voltage of the power supply will be increased to the level so that the wire will barely glow. Than, one half of the wire will be cooled with ice cube.</td></tr>
</table>

4.	Which prediction would correctly describe the effect of cooling on the remaining part of the wire? The glow of the *remaining* part : (a) will stay the same; (b) will be brighter; (c) will be dimmer.	In this "***predict***" part, every student has to formulate her personal, conceptually justified prediction.
5.	Justify your selection, using every possible argument. Try to make a clear predictive model (basic assumptions and reasoning patterns).	
6.	Discuss your selection and your justification with peers in your group and try to get a shared prediction and justification. (*Don't accept other's arguments until you are completely convinced.)*	In this "***predict***" part, the students are supposed (1) to present and discuss their predictions and justifications and (2) to try to build a shared prediction and justification. So, here a social cognition should happen.
7.	Describe the shared prediction and justification, describing explicitly basic assumption and reasoning patterns.	
8.	Describe the reasons due to which you changed or you did not change your original prediction and/or justification.	
Experiment was performed by the instructors.		
9.	Describe the outcome of the experiment as you have observed it.	In this "***observe***" part, the students are supposed (1) to observe and describe the change as it actually happened and (2) to compare it with group or personal prediction.
10.	Does the outcome of the experiment agree with the shared group prediction or with your original prediction in case you did not accept the group prediction? a) It agrees with group prediction. b) It agrees with my prediction c) Neither with group prediction, nor with my prediction.	
11.	In case of any disagreement between the prediction and outcome, detect possible errors in your basic assumptions and reasoning.	In this "***explain***" part, the students are supposed (1) to reconsider their original assumptions and reasoning which didn't lead to the observed change; (2) to invent a better predictive model.
12.	Describe basic assumptions and reasoning, which would give a correct prediction.	

Table 2 Different types of answers to questions 1 and 2 and corresponding numbers of occurrence.

Content	Number of girls who answered among 19
The wire will be hot and/or will get longer	13
The wire could affect a magnet or a compass	8
The wire will glow	2
The presence of the current in the wire is detected using ampermeter or voltmeter	4
The wire with current should oscillate	3
The wire with current should charge a piece of textile	1
The wire would cause a chemical reaction if put in water	1
Observable effects would increase, if battery voltage gets bigger	17
The number of ideas is larger than the number of students because some of them suggested more than one idea.	

4 THE MAIN RESULTS: COMPARING EXPERIENCES IN TRADITIONAL AND ACTIVE LEARNING ENVIRONMENT

After finishing the workshop activities girls gave their feedback on it. They evaluated the workshop idea, content, presented experiments, and their expectations and thoughts about their preferable teaching method. All students endorsed this active learning experience and would choose it rather than those having in their schools. Some students' comments on traditional learning environments using own experience in their school were selected as rather interesting and indicative ones:

- *Girl 1* said: "I prefer to learn physic using the active learning similar to this workshop. I wish to learn more during the class activities guided by my teachers instead of having them sitting at the class table in front us, telling us "imagine this and that" and never show us anything or very little of it".
- *Girl 2* said: This method of teaching and learning is more interesting and I prefer to figure out class content during the classes instead of sitting at home and trying to find my own way how to really learn it".
- *Girl 3* said: "Categorically, I prefer this physics class. In this way I learnt in only one hour more that I have been taught for three years in my school. I am glad to have an opportunity to compare this method and our everyday method which is not any active. I like more the chance that I can use here my eyes and my brain to understand the relationship between three physical quantities, and how they influence each other."

These responses prove the needs for a strong change in BiH curricula, and extensive preparations for such change. It will require implementation of new methods in teachers' training and education, better equipped schools' laboratories and more opportunities for students who need to have their active roles in the physics classes. The workshop's analysis showed that physics teachers should more classroom demonstrations and experiments in their lectures and help students learn physics by stimulating their interest. Even traditional demonstrations may not effectively help students [2] in understanding physics, although they have a significant role in the learning process. Results of this workshop suggest the need for higher awareness of BiH physics teachers of their role in physics education research. In addition, they need modifications of instructions in physics classes and should start using research activities to develop more effective curricula. That might facilitate the process of introducing student-centered learning-teaching strategies, what active learning is.

REFERENCES

[1] White R and Gunstone R 1992 Probing Understanding (London: Falmer Press)

[2] Crouch *et al* 2004 *Classroom demonstrations: Learning tools or entertainment?* Am. J. Phys. **72** (6) 835-838