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Experiments as a Basis of Informal In-service Training of Czech Physics Teachers

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Abstract. Experiments perform a number of functions in physics teaching - from a fun add-on of a very formal learning style to the cornerstone of a teaching method. A method of acquiring physical knowledge by using experiments, problem solving, tasks, etc. is a basic approach of teaching physics according to the Heureka (in English “Eureka”) project. Students are guided to analyse and solve scientific issues whereby they discover inquire new physical principles. The experiments are the main part of the work with the teachers, both in the long-term activities organized for the new participants of the Heureka project, and also in the workshops of the regional centres for physics teachers organized by Elixir to Schools. In this paper we will inform about our experience of working with teachers. The teachers' feedback to the project will be presented as a part of the study.

INTRODUCTION

The Heureka (in English “Eureka”) project is a long-term activity (it started in the beginning of the 1990's) based on the activating teaching method active work, both at school with students and in the teacher training. The teachers attending our seminars are engaged the same way as students at schools: they are instructed on problem solving experimenting and learning from one's mistakes. Our seminars provide a long-term systematic and intensive teachers' training series of seminars for the new participants. It takes ten weekends during the course of two years. That gives all participants the possibility and sufficient time to improve their capacities in teaching physics.

The character of the seminars is rather informal: the seminars are free of charge and teachers join Heureka on a voluntary basis gaining no formal advantages or benefits at their schools. The seminars are organised on the weekends with teachers staying (and sleeping) in the classrooms. More information about this project can be found in [1].

However, many physics teachers are keen to learn the new experiments, manufacture interesting teaching aids, share the joys and sorrows of everyday teacher's life, but they cannot attend the meetings and participate in the aforementioned seminars due to their agenda and distance from their respective homes. That is why we thought about how to assist them. Thanks to the financial support of the Česká Spořitelna Foundation, the regional centres for physics teachers were established in 2013. The organisation, Elixir to Schools now organizes the monthly meetings in 25 towns in the Czech Republic. More than 900 teachers regularly attend the meetings in its centres [2, 3].

EXPERIMENTS IN THE HEUREKA PROJECT

In the Heureka project we use the inquiry-based approach of teaching physics at schools. The hands-on experiments are used as the principal method for working with the students. We use all types of experiments described as a part of ISLE cycle in [4]: observational experiments, testing experiments and application experiments. The short

characteristics and examples from the school practice follow. As an example of the respective type of experiment we will present a part of the methodology of the “Archimedes principle”.

1. **Observational experiment** is a first type of experiments, which is utilised when the students start to investigate a new phenomenon. The students start each conceptual unit of the topic by observing carefully selected physical phenomena. Then the students come up with ideas and formulate rules to explain their experimental observations. The students are encouraged to suggest multiple explanations of the same experiment.

Example: When starting this new topic concerning buoyancy force, the teacher brings a glass vessel (aquarium) and several pieces of fruits (e.g. lemon, lime, orange, apple, and pear) to the classroom. The pupils guess whether different pieces of fruit float or sink (e.g. whole orange floats but peeled orange sinks; lemon usually floats, lime sinks). Then the students formulate that there must intervene some “force of water” acting on floating fruit. In the next step they think whether this “force of water” acts also on the object which sinks. They discover that a force meter shows less value when the hanging body is in the water than when it is in the air. Then the students think about the buoyancy force and formulate ideas such as what conditions could affect this force. Usually they suggest the volume of the body, the mass of the body, the shape of the body, the volume of liquid, the immersion depth of the body, the density of the liquid.

2. **Testing experiment** is a second type of experiments that students design when they need to test a hypothesis. The fact that all explanations of the observational experiment have equal weights before they are tested allows students to freely express their ideas, often based on everyday experience, without waiting for the validation by an authority. The students then have to come up with experiments that will test each of the proposed explanations/rules by predicting the outcomes of the new experiments using hypothetico-deductive reasoning (if-then).

Example: Each group of students chooses one of the condition they had come up with, and designs an experiment which proves/disproves whether this condition affects the force or not. For example, if the students investigate whether the buoyancy force depends on the volume of liquid, they need to compare this force acting on the same object in the water in different containers. After all experiments are finished, the groups present their results – how they carried out the experiment and what they found out. The Archimedes principle is then formulated.

3. The third type is an **application experiment**. In this type of experiment the students have to apply one or more concepts that they already know to solve a new problem.

Example: At the end of the topic “*Archimedes principle*” students have to solve the following problem: *A candle floats if put on the water but it is impossible to light it (it “lies” on the water). Arrange the floating candle in a manner that it can be lit. You have several things at your disposal (straws, sticks, corks, tape, etc.).*

The discussion about the students’ solutions is a necessary part of the activity.



(a)



(b)

FIGURE 1. a, b. Different solutions of the task.

The students appreciate the laboratory work done this way very much. Below a few quotes by the students are listed:

- “*In the lab I liked the fact that we showed what we had learned from the experiments and then I remembered it better.*”
- “*We tried different experiments on the subject and had to figure out how it worked. It was interesting for me.*”
- “*We invented the experiment ourselves and were able to express our ideas. It was great.*”

Archimedes principle is one of the topics in the seminar for the teachers on liquids and gases, too. In our experience, this topic is very hard for both students and teachers. During the seminar in March 2019 the teachers dealt with the lab work *Boat in the Pool* [5].

Several comments of the participants follow:

- *“Useful for me, especially to learn what suits us when working in pairs and what doesn't, and how the pupils might sometimes feel when they have trouble with understanding.”*
- *“Very difficult. Useful to experience what the pupil feels, to feel the joy of accomplishment and understanding one's needs.”*
- *“I was surprised by the difficulty of the Archimedes principle. Also, it is interesting how we approached the topic in a completely different way compared to the traditional one. There was also a lot of introspection because I got to know myself better through the presented way of thinking about things, where my limits are, that thinking is hard and that automatic thinking is not always the best. We also enjoyed experiencing the feelings of the children who are stuck in one place because advancing is for the time being beyond their abilities, so I definitely learned something from that.”*

From the evaluations it is evident that well-prepared experiments have a significant impact on pupils' and teachers' comprehension and scientific reasoning. And our thirty years of experience entirely confirm that.

FROM HEUREKA PROJECT TO ELIXIR TO SCHOOLS

As mentioned before, not all physics teachers in the Czech Republic want or are able to join to our long-term series of seminars. Not to mention that we are not able to organize the seminars for the thousands of teachers. But those who want to learn something new have the possibility to attend the regional centres by Elixir to Schools.

Mission

Elixir to Schools is committed to promoting innovative approaches in education by building capacities of teachers, improving accessibility to specialised information and strengthening the coordination of both formal and informal knowledge sharing mechanisms. Following the vision that every pupil studies with joy and takes advantage of his or her potential in its entirety, Elixir to Schools aims to respond to the challenges that the rapid transformation of the socio-cultural reality of 4.0 Industry and the introduction of technological innovations present to the education system. We aim to make peer education part of the system of teaching future teachers and in-service teacher education. Our long-term goal is to make every teacher in the Czech Republic know that Elixir is the place where s/he gains the necessary support for the implementation of interactive teaching.

Where We Stand

Physics is unfortunately for a long time the second least-favoured subject at schools [6]. It is thus not surprising that consequently there is a lack of technical professionals at the Czech labour market. If we want the students to be educated and to compete internationally in science and information literacy, and last but not least in life, it is necessary to change the approach to the way physics is taught at schools and to otherwise use digital media and technology in schools.

To tackle this issue, it is crucial to strengthen the teachers' competencies and to apply activating teaching methods more frequently to their own teaching. We are well aware that an average teacher has an outreach to about 2000 children throughout her/his professional career. If the teacher passes on the knowledge to his students in an eye-catching and attractive manner, the students are more keen on knowing more. As thus the learning process becomes widely effective. The report of the Czech School Inspectorate states that: *“The success of school pupils in science literacy is higher in schools where teachers use teaching methods to promote the development of science literacy, such as experiments, systematic observations of nature, analyzing data from tables and graphs, etc.”* [7]

Elixir to Schools is gradually changing the situation at schools where physics is often at the margins of interests for the majority of the students. The educational programme Heureka, originated in the Czech Republic in the 1990s, is based on participatory teaching activities and experiments through which the pupils and students practically test the scientific hypotheses and come to a better understanding of the world which surrounds them. Our projects aim to

introduce the use of experiments at schools to substitute the often not-so-engaging and unintelligible way of learning consisting of the mere presentation of the scientific facts by science teachers.

Centers for Collegial Education for Primary and Secondary School Teachers

Elixir to Schools established the centres of collegial education for the teachers of physics. Under the supervision of an experienced head of the centre and following the developed curricula, the teachers attend regular monthly meetings in the regional centres to learn about cutting edge methods and practices presented by centre chiefs and by other attending colleagues (sometimes also by external consultants). The established centres thus serve as platforms for knowledge sharing and debating, ultimately providing an opportunity to strengthen the professional networks. The centres are a meeting place where best practices and teachers' experiences are shared. The most important part of the programme forms doing experiments and building the new tools for experiments. The teachers also learn to reflect on their own professional experience and verify the impact on children's learning at school. Furthermore, they learn about engaging activating forms of teaching (research form of teaching, project teaching, and tandem) in the classroom.

At present, around 900 teachers from over 300 primary, junior and upper secondary schools throughout the country are regularly involved in the activities of Elixir. In 2018, the number increased by 150 physics teaching professionals. Each month, the teachers attend the meetings at one of the 25 regional Elixir centres in the country. Apart from monthly meetings at the regional centres, Elixir organises occasional meetings in six other cities (the term "flying centres" is used for those irregular meetings). 46 those meetings took place in 2018; for the first six months of 2019 16 meetings are scheduled. Although the physics teachers are the beneficiaries of the project activities, the impact of the project is to increase the number of technically educated people in the country who will be able to face the challenges of the 21st century.



(a)



(b)

FIGURE 2. a, b. Working atmosphere in the centre.

Preschool Education in Physics

The organization aims to expand its activities in the field of physics to reach out to the preschool level. Every child is naturally inquisitive and enthusiastic should s/he have a proper guidance. When we inspire children in the kindergarten at an early age, they will have a great basis to understand the more complex secrets of physics in the following levels of education: *"Science education in early childhood is of great importance to many aspects of a child's development, and researchers suggest that science education should begin during the early years of schooling. There are several reasons to start teaching science during the early childhood period. First, children have a natural tendency to enjoy observing and thinking about nature. Young children are motivated to explore the world around them, and early science experiences can capitalize on this inclination. Developmentally appropriate engagement with quality science learning experiences is vital to help children understand the world, collect and organize information, apply and test ideas, and develop positive attitudes toward science. Quality science learning experiences provide a solid foundation for the subsequent development of scientific concepts that children will encounter throughout their academic lives."*[8]

Preschool teachers are often afraid to do physical experiments with children since they do not have high consideration of their own knowledge of physics. There are professional activities in the Czech Republic that help teachers in kindergartens and primary schools in this area [9], but the coverage of those activities is marginal and only a small number of teachers participates in them. Thanks to the latest Project of Elixir a higher number of preschool teachers are assisted in encouraging the children to carry out simple experiments and “magic” while engaging natural elements such as air and water to get to know the world which surrounds them.

The programme is designed for the teachers in pre-school and younger school education to open the world of science to young children. Furthermore, its goal is to encourage and develop natural interest in science from an early stage and boost the development of science literacy among the pre-school and younger school-age children.

In a practical way, through the demonstration of simple experiments and the explanation of physical laws, the teacher acquires the knowledge of how to involve the experimental methods to enable children to explore and understand how the world around them works.

To consolidate the newly acquired knowledge, the teachers are also trained and prepared to educate the children about the follow-up activities such as drawing pictures of experiments after each meeting.



(a)



(b)

FIGURE 3. a, b. Experiments from optics in the preschool.

Participants' Feedback

Monitoring and evaluation of the Project outputs is an inherent part of the organization's activities. Both written and oral feedback are sought after by the project managers and supervisors in order to identify how best to carry on with the activities and meet the needs of the involved teachers and other education professionals. Below several evaluations of the activities by the project participants are listed:

- “Elixir seems to me as a stimulating project. It is possible for me to get acquainted with physics and to engage the cutting edge knowledge in the classroom. By choosing individual topics for each meeting, the selected chapters from physics are highlighted and discussed from the perspective of how to present them to the students in an engaging and smart manner. Thanks to the experienced teacher, who supervises each Elixir meeting, the array of topics is anything but scarce. I greatly appreciate her activity and diligence. She is always well prepared and brings in materials for making learning aids, which are produced following her instructions. These are often quite original items that will surely inspire many students in the classroom. I hence see the impact of Elixir primarily in providing the opportunity of experience and information sharing in teaching physics and, last but not least, in unfolding and boosting creativity.”
- “Elixir to Schools offered to me an inspiration for teaching, provided instructions for explaining the subject matter, gave me some ideas for experiments, projects and exciting excursion tips. Other benefits are meetings with fellow teachers who share their experiences and guidelines. I have to admit that right prior the meeting I always feel like skipping it in the midst of my busy agenda. However, this feeling upon arrival passes quickly especially after making coffee and the introduction. The bonus is also the opportunity to vote on a seminar topic.”

- *Elixir to Schools ranks for us first in the teacher-training events and activities as the project is indeed beneficial for us. We appreciate the organization, topics, lecturer's readiness and finally the pleasant atmosphere. We have utilized a number of ideas and tips acquired within the Elixir meetings in the classrooms instructing the middle school and high school students of physics. In the previous school year as well as in the current one we used the gained information from Elixir for the tandem lessons. We look forward to each meeting. We are also satisfied that the Elixir takes place in our town. We wish you a nice and peaceful holiday and by 2019 a lot of health, a bit of luck, well-being and no stress."*
- *"For 5 years, Elixir to Schools has been an inspiration in physics, a place where I can meet enthusiastic and creative physicists, a space for exchanging ideas, experiences and consulting problems, just like the Heureka project used to be in the past. I consider Elixir to be a vital source of skills which I readily share with my students. My thanks go mainly to the head of our Pilsen centre, but also to others who are involved in the planning of Elixir events and are in charge of the project."*

CONCLUSION

As of now, Heureka project and Elixir to Schools have contributed to the establishment and existence of a stable and active network of secondary school physics teachers based of volunteering, regularity and collegiality throughout the regions of the Czech Republic. Currently we are working on the project development of the centres of peer education for kindergarten and primary school teachers.

The students who are already taught by the teachers involved in the projects are gradually changing their mind, their ability of scientific reasoning is growing [1]. The projects outcomes have become and continue to be an inspiration for the similar emerging projects in the non-profit sector. Both projects differ from the similar initiatives mainly by focusing on the real long-term changes in the education system, and strategically targeting sustainability. The projects are built from the bottom, rely on the voluntary participation free of charge, and boast a long tradition.

Our main goal is to make every teacher in the Czech Republic know that Heureka and Elixir are the places where s/he gains the necessary support for the implementation of interactive teaching.

ACKNOWLEDGMENTS

Initially Heureka had operated without financial support. Subsequently the situation changed for better. Nowadays Heureka is supported by the Faculty of Mathematics and Physics, Charles University in Prague and by Elixir to Schools, too. The financial and expert participation allows for organizing of the seminars and meetings. Faculty of Mathematics and Physics gives the Heureka project not only financial support, but also the necessary technical, administrative and expert background.

Thanks to the financial support of Česká Spořitelna Foundation Elixir to Schools was initiated and continues to expand the outreach of the projects.

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