The possible uses of special materials and multimedia devices in high school physics education and in the dissemination of scientific knowledge

Tibor Medvegy

Supervisor: Associate Professor András Juhász

Eötvös Loránd University
Faculty of Science
Ph.D. School in Physics
Director: Professor Tamás Tél

Physics Education Ph.D. Program
Director: Professor Tamás Tél

2017
**Introduction:**

Numerous theses, conferences, articles and doctoral dissertations have dealt with the problems of domestic public education, including physics education. Both domestic and international research agree that the attitudes of students to physics as a subject are very low, in fact, in many cases it is the lowest. The solution to this problem can be, among other things, the more frequent use of experiments, involving well-known and everyday tools in knowledge transfer and raising awareness of the role of physics in everyday life.

**Objectives:**

The aim of my doctoral work was to develop methods that could improve the attitudes of high school students towards the physical and technical sciences. My objectives are summarized in the following points:

- Understandably summarize the physical causes of special behavior of so-called intelligent fluids for high school students. And through the presentation of these materials, to show high school students how close is the relationship of the technologies surrounding us to physics.
- Collecting exciting and interesting experiments, and developing innovative experimental arrangements linked to special materials (intelligent fluids and liquid nitrogen), which can make presentations on such topics more interesting.
- Involving multimedia devices in education, which are important and familiar to high school students, to improve students' attitudes towards technical and natural sciences.
Theses:

1. In my work I have developed a methodology, how to familiarize high school students with the physical causes of the special rheological behavior of the so called electrorheological and magnetorheological fluids through laboratory demonstrations as well as experimental investigations.

Publications related to the thesis: [1], [2], [3], [4]

If we look around in the world of technology, we will notice that surrounding objects we use in everyday life are becoming smarter. The TVs, refrigerators, washing machines, telephones, watches and even the houses are getting smarter, they include more sensors and actuators and possess more PC-like functions. This change does not only concern our devices, but also the materials used in them. Modern material science refers these as smart materials, which includes electro- and magnetorheological fluids. The electrorheological and magnetorheological fluids are complex liquids which can rearrange their structures in the presence of an electric or magnetic field. Due to these structural changes, depending on the strength of the outer space, the viscosity of the liquid may increase by several order of magnitude. Due to their controllable viscosity, these fluids have become increasingly popular in modern engineering disciplines. Used for example in the shock absorbers of cars, to reduce the vibration of washing machines, to reduce the oscillations of stepper motor rotors, in brakes and in clutches for torque transmission, or in the field of medical science for delivery of active agents. In my research I have examined the technical usability of these fluids in several cases, during that I became more and more familiar with the topic and the ongoing researches. I used this knowledge for motivational purposes to introduce during lectures these advanced materials and the technologies made possible by them. For these presentations I have developed methodology, demonstrational and measurement experiments so that I can present this modern topic to the interested students as efficiently and as clearly as possible.
2. I have designed and constructed a new type of ferrofluidum core differential transformer tilt and acceleration sensor. In this work, within the framework of the Research Students Movement, under my tutorship attended a high school student, Áron Molnár. During this research project, the participating student gained a deep insight not only into the physical background of the operation of intelligent fluids, but also in physical and technical knowledge beyond the secondary school curriculum. And he became familiar with the research and development and scientific methodology in detail.

Publication related to the thesis: [5]

An LVDT (Linear Variable Differential Transformer) is a sensor, which is used to measure linear displacement and consists of one iron core and three coils. The coils take place next to each other, the primer in the middle, and the two reverse-coiled secondary coils in the edges. The primer coil is usually excited with a frequency of 1 to 20 kHz and an excitation voltage range of 1 to 24 V rms, so depending on the iron core’s position different voltages are being generated in the secondary coils, which voltages’ subtraction gives the output of the sensor. In our solution, we replaced the iron core with a glass tube cell filled with ferrofluid. In this way, we get a Ferrofluid Core Differential Transformer – hereinafter referred to as FCDT. In the horizontal state of the cell the ferrofluid distributes equally in the space surrounded by the coils. Nevertheless, when we rotate or accelerate the sensor (in the direction of the coils’ axes), there is a different amount of ferrofluid in the three spaces. The result is similar to when the LVDT’s iron core is being moved, the generated voltages in the secondary coils are changing, so the cell’s acceleration or tilt can be measured. After the prototype was prepared we aimed to increase the sensitivity and broaden the linearity range, which we achieved by using different layouts.

One of the main results of the research project was the development of a new measurement method, but it is not negligible that it has also been proven that the subject of intelligent materials is suitable for attracting secondary school students to technical and natural sciences.

The project, under my tutorship, has been presented by Áron in many domestic and international competitions, where he has achieved remarkable results.
We also wrote a joint publication on the results of the project with my student, which was published in the famous Journal of Magnetism and Magnetic Materials titled „Analysis of a ferrofluid core differential transformer tilt measurement sensor“. With my leadership, Áron has actively participated in all stages of the research, starting with the initial idea through the theoretical description to the actual measurements and to the publication of the results. The necessary skills he did not possess before the project (e.g. LabVIEW programming, professional English language, physical background knowledge about ferrofluids and the LVDT, PCB design and implementation), he acquired them during the project.

3. I developed a collection of eye-catching demonstration experiments using liquefied nitrogen, which I have presented in many schools, summer camps and in science promotion programs. For a collection of nearly 70 experiments, I made a video tutorial, which will assist teachers who wish to reproduce the experiment in training and in carrying out of the experiments.

Nitrogen makes up to 78% V / V of our atmosphere, so we can rightly call it everyday material. However, in its liquid form it is very special and interesting for young people. Liquid nitrogen is therefore one of the almost unvi able features of science-promoting experimental presentations, using it one can use to carry out many spectacular and instructive experiments. As a high school teacher and also as a university lecturer, I held a numerous demonstrational experiments using liquid nitrogen for from kindergartens to primary and secondary school students, to university students, workers and retired people alike. Liquid nitrogen has proved to be very useful in raising interest in physics and promoting science as well. During the preparation for the lectures I worked out a collection of nearly seventy experiments. During the preparation and presentation of these experiments I have gained a lot of experience. I recorded these experiences and ideas as video tutorials for teachers who wish to reproduce the experiments. The collected experiments were divided into five major themes based on their topic and I published the five videos free of charge on the Internet via YouTube.
4. I've shown how widely smartphones can be used in secondary school physics. I presented how the operation of electronic sensors of the modern age can be introduced to with the help of smartphones. I have worked out competition exercises at the József Hlavay National Environmental Science and Technology Student Conferences for Junior Engineering Contest and Physics Competition categories, which competitors could solve with the use of smartphones.

Publication related to the thesis: [6]

The devices of the modern age of communication - and the entertainment industry will increasingly find their into students' lives. In most classes, there are no students who have no smartphone or tablet PCs. These hardware include a number of sensors and software that can be used to process data from them. Which can be compared in their usability with the traditional tools of physics education. In general, mobile phones with PC-like features are called smartphones. With the rapid worldwide spread of these devices, so in the pocket of most students is pelting a device which computing capacity far outweighs the capacity of NASA's computer’s in the year of the Moon landing. These devices include a processor, internal and removable memory, and it can be controlled over a touch screen. Most devices are also equipped with GPS, camera, WiFi and Bluetooth communication, and perhaps the most important for physics education, with different sensors. With these sensors, a number of new experimental layouts become feasible in classrooms and student circles. During my work I have developed several measurement layouts, and I worked out exercises for József Hlavay National Environmental Science and Technology Student Conference Junior Engineering Contest and Physics Competition categories yearly organized by the Faculty of Engineering of the University of Pannonia, which the students had to solve with the help of their smartphones.
5. I have developed a collection of experiments related to the mechanics curriculum, which uses the Nintendo WiiMote - a wireless game controller for a video game console - as a demonstrational and a measuring tool. I have shown that during the teaching of the mechanics a lot of experiments can be presented using the WiiMote, which will be more interesting by replacing a classical tool in an experiment, or even entirely novel experimental arrangements become possible. I made a software, which facilitates data collection, calibration and saving data to a file for physics teachers who want to apply the method I have developed.

Publication related to the thesis: [7]

The Nintendo Wii console remote controller is the WiiMote, a battery-powered wireless unit which includes a 3-axis accelerometer and an infrared camera. The special feature of the remote controller is that it is not the camera's picture being transmitted to the receiver via Bluetooth, but only the apparent coordinates of the four brightest infrared sources seen by the camera, resulting in very fast data transfer. This feature makes the device extremely useful for physics education, since a simple infrared light sources can easily fixed to different experimental devices and can be tracked in real time. This solution is very cost-effective through the WiiMote cheapness, yet it creates eye-catching experimental layouts close to youth. During my work, I developed a collection of demonstration and measurement experiments related to secondary school mechanics, which are related to both kinematics and dynamics.
Utilization of results, additional plans:

My briefly introduced results were aimed primarily at assisting in physical education. All the methods I have developed, have been tried many times in practice, and on the basis of the experience gained in this regard, and on the feedback I have received, I continuously developed them. My results can be utilized by other physics teachers, and I helped them through publications and video tutorials.

I presented lectures on special materials (intelligent liquids and liquid nitrogen) on numerous occasions. On the basis of the feedback, the opinions of the teacher colleagues and the visitors of the lectures were unanimously positive. I plan to further expand the collection of liquid nitrogen experiments in the future and to publish a more detailed description of the experiments besides the videos.

Some of the students who participated in my lecture on intelligent material later started on research. Under my tutorship within the framework of the Research Students' Movement they examined issues related to ferrofluids. One of the most successful of these topics was the inclination sensor using ferrofluidum, which I plan to further develop and patent.

Experiments with both smartphones and WiiMote have brought new features to the lives of physics lessons, classroom sessions and competitions that I have spent time for was repeatedly reimbursed. Experiments with these tools have seriously attracted interest from high school students. With the inclusion of smartphones in competitions, I managed to develop novel practical competition exercises which are deviate from the usual theoretical competition tasks. I received positive feedback from the teachers as well as from the contestants.

With the rapid development of smartphones, additional sensors are expected to emerge. More and more models include gyroscopes and light intensity sensors. As soon as I have the opportunity, I would like to look at the applications of these sensors in more detail.

Many of my teacher colleagues tried the methods I have developed for teaching physics using the WiiMote, and their suggestions and ideas were continually been integrated into my work. Based on their opinions, tried-and-tested applications were useful and improved the attitudes of students to physical and technical sciences. Later I plan to involve additional teachers, so that I can gather as many opinions and ideas as possible to change the software that I have made on demand.
Publications related to the thesis:


Further publications:

Conference presentations:


International conference materials:


Hungarian conference materials: