Teaching astronomy paying special attention to today's results of scientific research

PhD Theses

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Introduction

The need of scientific, technical and mathematical knowledge for everyday people is at its peak. Furthermore, in our days it is easiest ever to reach information (I also mean the internet access in and out of school). At the same time the science related subjects, such as chemistry and physics are in the leading role of the least popular subjects. The goal of the most of didactic research is to make these STEM subjects more popular. One of the most effective ways of solving this problem is teaching astronomy paying special attention to the most recent results of the topic.

Some of the most rapidly developing research topics are astronomy and space research, and their leading topics, namely astrobiology, exoplanets, and the research of our cosmic surroundings, the Solar System focusing on the hazardous celestial bodies (the asteroids and comets). We need to note the investigation and discovery of the gravitational waves that ensures us to better understand the structure, the development of the Universe. The results of these areas are often present, therefore everybody, including our students and pupils have information about these. The latest results of the most important astronomical research should be put in curricula, and we need to work find new and effective ways to transfer these to our students for their benefits. Nowadays researchers and teachers work together helping each other, space agencies observatories or even university departments consider reporting their results also for the public. The materials these media provide can be well used in teaching since they are simplified and include demonstrative information.

I have experienced that though the students are very interested they show low competency in astronomy. Teaching more astronomy could contribute to enrich their scientific, mostly physics related knowledge, therefore building a true worldview and logical thinking. It is difficult to appoint the content we would like to cover in the curricula, since as we are lack of time, we can not teach enough. Therefore, we need to concentrate on the ones that are crucial to find the way in the astronomical news, support the better understanding our place in the Universe, to sharper see our possibilities, to better build a scientific thinking in order to better equip our students against fake or pseudo-science.

Astronomy is unique among science subjects in a way, since it is also a hobby for many, like amateur astronomers. Astronomy has a nature to provide enjoyable experience, to raise and easily fulfil interest. In addition, it provides useful information for mankind. Let’s just think about finding our ways in any time or any place. Frequently not the results or discoveries themselves are in the focus of importance, but the methods, equipment or tools are considered as very useful in our everyday life. We can now specify the development of photography or data processing, or the everyday use of newly invented materials for space research. Students with special interest in arts are closely related to astronomy too. They find that poets, writers, artists use celestial bodies and phenomena with favour in their artistic pieces. When we teach about the discovery

of certain celestial bodies that are similar to one well known from sci-fi or popular movies or novels, they are highly motivated and surprised. Tatooine from the Star Wars trilogy is a great example to this. We can also enrich the palette of our teaching tools using artistic pictures, or movies, surely with ones that are similar to reality. And we can find a multitude of these.

In my thesis I concentrate on teaching comets, exoplanets and astrobiological issues. These topics got highlighted in scientific research in the past decades. They raise our students' interest, so those who have no special affection towards science can easily be invited to learn about physics concepts and phenomena. Students who have interest and gift for astronomy have a chance to blossom and to measure their knowledge in competitions. Astronomy mentoring, its birth and development is presented by concentrating on the International Olympiad on Astronomy and Astrophysics.

Thesis 1

Teaching comets related content

I made a survey on the concept of the students on comets. I showed that there are numerous misconceptions. We taught and reinforced the correct knowledge with a programme focusing on comets. We changed the incorrect points to correct, scientific ones. I developed a project covering comets for normal classroom use for a few sessions' time-period. Based on my experience providing enough information in advance we can forego the evolution of the fears that are often caused by the media. [S1]

Comets have always grabbed the imagination of mankind. Often fears and tragedy got connected to their presence. Later a hunt occurred, and we became richer with numerous astronomical observations. But we could get closer to their true manner and characteristics from the observations made by space equipment in the last decades.

Our students have never seen any comets, so they were poorly informed in the topic. Most of them thought comets were shooting stars. They had the idea that the tail of the comets are always in the opposite direction to their movement's direction. We taught them about the case when the tail is "pulled" in front of the core itself, making the idea clear that the direction of the tail is determined by the solar wind. The luminosity of the comet was connected to fire or burning in their knowledge, which idea shouts out for correction. According to their ideas only a dense gas set can be seen, so they got amazed to acknowledge that the tail is of a rare substance. Sometimes students could not give a correct estimation to the measures and content of the comets. Nearly each of them considers comets dangerous, I find this idea parallel to the science fiction moving featuring catastrophe with comets hitting the Earth. Based on my experience talking

about the probability of a comet hitting the Earth can ease this fear. I emphasize the importance of discussing astronomical forecast and correct understanding of statements of different probability. Doing so we can forego the evolution of possible fears regarding astronomy. Media react very rapidly to unknown, rare or even spectacular celestial phenomena. Sometimes students can be informed sooner than their teachers, but it is still worth discussing the related issues, their scientific background, even is respectively since these are often missed out from the news broadcasts or are of less importance.

In our curricula comets are recommended for a one lesson study mostly in geography. It is sure not enough to gain persevering knowledge. Expecting comet ISON (this phenomenon unfortunately did not happen as a spectacular celestial phenomenon), later the success of Rosetta mission gave excellent opportunity to maintain the interest towards comets for years, which according to my opinion was a great help and contribution to gain deeper understanding and get more information about comets.

Thesis 2.

Making a model of the comet's core

We made an experimental model that can model the comet and its appearance on the sky. I studied and worked out how to make a model safe students' activity for the comet core. According to my experience this experimental model can be a great help for deeper understanding. [S1]

When making a model we showed a similar copy of the comet's core, we also mentioned the main differences between the model and the real meanwhile. The basic ingredients of the core were all included in the model, but their ratio was not necessarily be punctually real. The inner structure became porous after a while because of the rapid sublimation of carbon dioxide. This is a real phenomenon. Using coal dust we could model the fact that the core is black. The most spectacular part of comet is the tail. We could model it, though the size in the model was very small. We put emphasis on the difference between real and model in this question.

I studied the possibility of making a hands-on model by our students. Based on this work I developed a method which can be safely done by our students in classroom settings. The crinkling of the comet core provided lifelong lasting experience not only for the students who were actually doing the activity, but their schoolmates who were just supporting them from a distance.

I compared my results with other studies and I found that the changes they offered definitely developed our solution for better, like I its black appearance, its safety and changed the duties necessarily done after the activity for better.

Thesis 3

Finding new ways to teaching Kepler's laws

According to my experience Kepler's laws can better and deeper understood if we use historical issues and latest scientific results in our methodology. [S2]

Stories taken from Kepler's life we can make our lessons more interesting. We can make a connection to e scene in the "The tragedy of mankind" to literature studies. We can mention astrology underlining its fake or pseudoscience manner. I find it important because many believe in it.

The visible motion of the planets in the sky is not well known, so I find it important to present it because the changes of the cosmic models are a result of their studies. Official definitions for planets became crucial (just like in the cases of other celestial bodied in the Solar System).

It is important to note that Kepler's laws apply not only for the planets of the Solar system, but also for moons and satellites. We can find problems or exercises in our course books or manuals in which from data of orbiting moons or satellites (like time period and semi-major axis of an elliptical orbit) other data, the mass of the planet (exactly the masses of the planet-moon system) could be derived. I highlight it because this new method of mass measurement is a great eureka experience for our students.

I recognized that the deep understanding of Kepler's laws can be helped by studying orbits of exoplanets. The orbits of the planets in our solar system are barely different from circles. Whereas studying exoplanets' orbits we can find ellipse of great eccentricity, ones that are similar to the orbits of comets. Our solar system is a one-centred model, however most of the stars are not solitary. In such solar systems exoplanets were discovered, and their orbits are not simple conical sections. The n-body problem is not in the secondary curricula since its mathematical background is highly complicated. But this problem can be discussed and studied using simulations as a didactical tool, and these displays can amuse our students. The study of changing certain parameters (like distance or mass) seems to be an eye-opening experience for them, while they can gain knowledge pointing far beyond secondary school level.

Thesis 4

Teaching the colourful world of exoplanets in physics class

Exoplanets grab our students' attention; it is the same even in the case of students lacking interest is science subjects. I made a survey to investigate at what degree our students are familiar with the topic. I got proof from the investigation that they barely know them. Furthermore, I found proof that even my practicing physics teacher colleagues have limited knowledge and information. Therefore, it should provide special didactical and methodological material for them, which would be also good for art-oriented classes. [S3], [S5], [S9].

The theme of exoplanets got in the focus in many ways: partly in the focus of scientific research, on the other hand in the focus of social interest. Michel Mayort and Didier Queloz were awarded the Nobel Prize in 2019 to reward their discovery of exoplanets orbiting a sunlike star. The topic is not brand new as the knowledge gained for the binary star systems can be easily applied for star-exoplanet systems too. The effects are the same, just smaller therefore harder measurable ones. The development of technical background was needed to reach the precision required for measurements to derive us to discovering exoplanets.

Our students are very fond of computer games, in virtual reality they can get experience of conquering new places, planets. Special far worlds can appear as scenes in popular tv or movie series. I showed that reality is at least as interesting, colourful, worthy of studies as what our imagination created about the exoplanets. I recognized do not have a precise definition of planets. Research done in the Solar System, in finding the celestial bodies rose a need to determine the minimum mass of a planet. Research done in exoplanets rose the question of the maximum value of mass, which information can make the difference between the brown dwarves and exoplanets. Learning about the history of the question and the definition itself can be very motivating and useful not only for our teacher colleagues, but also for our students. This question can also reinforce the knowledge about other astronomical bodies like stars.

I made an overview of the best international practices; I followed their development attentively. I analysed the possibility of their implementation into the Hungarian practice. I summarize my recommendation in my theses.

I made my student familiar with the scientifically reliable sources. These I list in my theses. I motivated them to pass their competencies on, so in project fairs or is competitions with their presentations they can enlarge the desire to dig deeper in a topic.

Thesis 5

Exoplanets related exercises and problems in physics teaching

We can give exercises or problems related to exoplanets to our students even without prior knowledge. Doing so they can gain new information and skills. I worked in a team that made an exercise and problem thematic collection on exoplanets. This is in e-book format and has recently been published also in English. [S4], [S6], [S7]

In this set of exercises and problems we use real data and information in order to promote the results of real measurements. Data can be read from real graphs of luminosity versus time graphs, or they can plot graphs from tables containing real data. Thus, they can get a glimpse of the work of astronomers. The trial use of the collection was in the mentoring sessions for astronomy Olympiads. I understand that in mentoring classes or courses more difficult problems are of great use and importance.

Of course, the simpler exercises can also be used in class. Most of the problems on exoplanets do not require any prior knowledge, they can be understood and solved with a few lines of introductory text. This is why exoplanet examples may have appeared as graduation tasks sooner than they would have appeared in the graduation requirements or textbooks. They are also a popular topic for competitions. I have found that these exercises can be used in mathematics classes, helping to practice mathematical reading comprehension.

In the teaching experience of the exoplanets the method of their discovery has the emphasis on. Therefore, in our collection a whole chapter is dedicated to this type of exercises and problems. Teaching and understanding special relativity is a very problematic task for secondary methodology. Whilst one of the investigative methods for exoplanets, namely the gravitational lens effect can very well demonstrate and prove the theory for our students. A problem to practice this would be overwhelming at secondary level according to my experience. Even though spectacular animations can perfectly demonstrate the theory thus helping the students to better understanding and more thorough memorization.

Thesis 6

Teaching astrobiology

One of the key issues of mankind since ancient times is if we are alone in the Universe. The search for intelligent life outside the Earth is a very attractive topic for students. In my experience, the high interest in this topic among our students is not matched by a sufficient knowledge, therefore, I have developed a specialised astrobiology course. My students were keen to learn about astrobiology, and many of them chose it as a topic for competitions. [S8]

I consider for the students, the goal of getting to know their closer and wider (even cosmic) surroundings is very important. Not just by listing knowledge and facts, but by showing the diversity of conditions outside the Earth and comparing them with the Earth's environment. The question of whether we are alone in the Universe or whether there are intelligent beings elsewhere is a question that is as old as humanity itself. We do not yet know of any life forms other than those on Earth, so astrobiologists are looking for conditions similar to those on our planet. We know that organisms have been found in almost all kinds of extreme terrestrial locations, with water as a fundamental component. So the first step is to look for (liquid) water in the Universe.

Our students first need to acknowledge that we do not have a chance to move to other planets, moons or artificial satellites, therefore we need to delicately look after Earth and ensure its habitability. This takes sustainable development into the picture. Astrobiological notions and phenomena helps our students create a better view about our place and possibilities in the world.

I have developed a specialised theme for this topic. In each session, we examined the (physical) conditions of life, learning about extremophile life forms living in extreme conditions. We discussed the characteristics of the celestial bodies of the Solar System and their habitability, with special attention to Mars, Jupiter's moon Europa and Saturn's moons Enceladus and Titan. Outside the Solar System, exoplanets were studied for habitability. We also dealt with famous problems such as the Drake equation and the Fermi paradox, and SETI research. It is also interesting to think about what it would mean if we knew for sure that we were not alone in the Universe, if we encountered extraterrestrial beings (whether we would even recognise them, whether we could communicate with them).

My students made severe preparation for competitions. In this project they made a survey in their school, they having these data analysed the saw and displayed the poor level of knowledge that is of their schoolmates. Having that result they planned a short presentation for them in which they shared their knowledge about current results of science regarding the search for extraterrestrial life.

Thesis 7

Mentoring work in astronomy

Perhaps the highest level of astronomy talent development is the preparation for the International Olympiad on Astronomy and Astrophysics. The selection and preparation of the Olympic framework is a collaboration between researchers, academics and secondary school teachers. This growing group includes students, PhD students and former Olympic team members. We have recognised that to select the right students, it is important that as many physics teachers as possible are familiar with this student Olympiad and the pathway to it, with the national selection competitions. We have developed a multi-round national astronomy competition and then a multi-stage preparation process for the top performers. We recognised that efficiency could be increased by giving weekly assignments to the students who were preparing, with the returned corrections pointing out their shortcomings in a personalised way. [S10]

I played a major role in raising awareness of the International Olympiad on Astronomy and Astrophysics, which grew out of the International Physics Olympiad, not only by presenting it at a physics teacher's conference but also by writing an article on the most important facts about it. Involved in the selection competitions and the preparation, my main goal was to increase efficiency, which was achieved by the following.

Initially there was just one national astronomy competition, but now there are several rounds of competition to select the next student Olympic team. After the three rounds, there are the national finals, followed by the Olympic preparations. The process of preparation has also changed over the years in order to be more effective. The effective training of students takes place in intensive preparation weekends and preparation camps. We have recognised that the in-between periods can also be used effectively in the preparation, with weekly assignments and then individually assessed corrections to point out errors. We have seen an increase in the success of students who have participated in astronomy Olympic preparation for several years, and we therefore give students other than the five frames and the reserve competitors the opportunity to participate in the preparation.

Astronomical specialized mentoring classes are organized all over our country, just like the ones for physics. The former Olympic team members are happily involved the mentoring work. I highlight two advantages of this. These recruit scientists are close to the chosen students according to their age. On the other hand, they have worked through the session, so they can build on their personal experience. We developed aids and

excipients that are accessible for the public. (in Hungarian: http://www.bajaobs.hu/ioaa/) This can succour starting mentoring classes anywhere in the country or it can give assistance to students or teachers when preparing for the competition.

IOAA was organized in Hungary in 2019. Therefore, we could launch two teams in the event. Four members of the teams were awarded with bronze medal. all others with honourable mention. This event promoted astronomy and physics; many students nationwide got extra motivation to study these subjects.

Summary

My work has focused on areas of astronomy that have been neglected in education, despite the fact that they are today's priority research areas, and their results are often in the news. I was pleased to see that researchers and astronomers consider it important to communicate their results, and so they produce material that is understandable at secondary school level. Larger space organisations (NASA, ESA) also employ teachers to develop a methodology for the transfer of knowledge and to help teachers in schools. As I mentioned in the introduction, there have never been so many opportunities to acquire (astronomical) knowledge, nor have there been so many teaching aids available to teachers. I have participated in webinars presenting educational materials, where the authors themselves present their materials on a particular topic. I have tried to raise awareness of these opportunities among my teaching colleagues in various ways (lectures, workshops, articles). Although the learning and teaching methods are becoming more and more enjoyable and effective, and a lot of simulations, images and short films help understanding, but even these methods do not save time and energy to achieve lasting knowledge and a correct scientific world view. I plan to continue to follow new international and national ideas and good practices, and to help adapt them to teaching in Hungary.

Nowadays, great emphasis is put on raising girls' interest in science, which can be easily achieved through astronomy. A new endeavour is the joint acquisition of knowledge by the family, which can also be easily achieved through astronomy programmes. Community involvement in research and participation in "citizen science" projects is becoming increasingly popular abroad. In these, people can research real data sets and gain knowledge about a scientific topic. Many of these are astronomical, and I plan to look into their use in education.

Own publications related to the theses:

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[S2] Horváth Zsuzsa, Érdi Bálint: Kepler és törvényeinek tanítása, Természettudomány tanítása korszerűen és vonzóan, Főszerkesztő: Tasnádi Péter, ELTE TTK, Budapest, 2011, pp. 424-429.

[S3] Horváth Zsuzsa, Bérczi Szaniszló: Az exobolygók sokszínű világa, A fizika, matematika és művészet találkozása az oktatásban, kutatásban, Konferenciakötet, ELTE Budapest, 2013, pp. 215-222.

[S4] Horváth Zsuzsa, Érdi Bálint: Exobolygók a fizika érettségin I.-II., Fizikai Szemle 2013/1, pp. 14.-18. Fizikai Szemle 2013/2, pp. 60-62.

[S5] Horváth Zsuzsa: Exobolygók minden szinten, Fizikai Szemle 2017/3, pp. 93-99.

[S6] Gróf Andrea, Horváth Zsuzsa: Exobolygók és űreszközök (Válogatott középiskolás feladatok a csillagászat és űrkutatás modern eredményeihez), http://fiztan.phd.elte.hu/kozkincs/kiadvanyok/index.html

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[S10] Hegedűs Tibor, Horváth Zsuzsa, Udvardi Imre: Csillagászati Diákolimpia Magyarországon, Fizikai Szemle 2015/9, pp. 319-325.