THESES OF THE PH.D DISSERTATION

Interdisciplinary approaches to physics and chemistry teaching at the high school level

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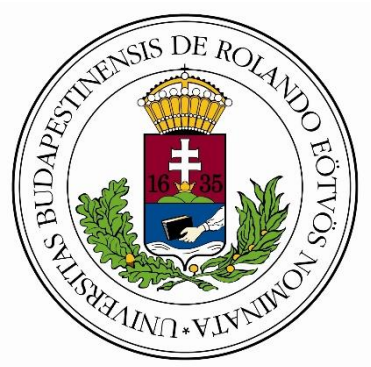

Eötvös Loránd University
Faculty of Science

2018.

Introduction:

In our present world, the science and technical knowledge is important not only for industrial and economic growth, but also for an individual person to circumnavigate everyday life in a tech stuffed world. The school taught natural science classes provide the base for these kind of knowledge with a well-structured learning curve to avoid the empiric or heuristic understanding. In addition, physic, chemistry, and biology classes teach students critical thinking. These subjects are based on the relationship of causes and effects, and they show how things are built up in a logical way.

Traditionally science education is classified into various subjects, however, this result in a situation where the students are hardly able to link together the same phenomenon learned at different classes. Therefore, it is important to draw the students' attention to these overlapping points since these areas are interesting and therefore raise more curiosity. This can be done also by teaching those phenomena of nature that are overlapping in various subjects. However, I would like to emphasize that my goal is not to integrate all of the various subjects into one class. I think this complex science approach needs to be developed along the individual subjects, which is the main study of my Ph.D. dissertation, also pertaining to this approach I developed teaching methods and exercises.

Aims:

The main goals of my Ph.D. work were to identify the overlapping points in the curriculum of high school level physics and chemistry subjects and to develop a teaching method that helps to connect the terminology and approaches of the various subjects. The subsections of the main goals were the followings:

- Developed a teaching method to couple the knowledge of the operative curriculum of the chemistry and physics subjects and to maximize that implementation between these two subjects
- Created worksheets and project works for students in which the interdisciplinarity comes true
- Introduced and developed activities to present the interdisciplinary approach that are capable to be used in a broad area at various levels (classroom activity, extracurricular activity, competition preparation, etc.) and for students with various age, background, and interests.

Theses:

Thesis 1.

I summarized and introduced the overlaps in the syllabus of high school level physics and chemistry subjects by clear examples. I successfully used this systematized data during my courses to deepen the scientific approach as well as the chemistry and physics knowledge of my students.

There are many overlaps in the high school level physics and chemistry syllabus. In some cases, the curriculum, textbooks, and teachers highlight these and draw the attention of the students, however, many topics are still underdeveloped and unused based on my personal experiences. As a result, the above-mentioned goals in terms of the students' thought process and scientific approach are not reached and in some cases even negatively affected by the absences. As an example, a new terminology might appear to students without any introduction or precursor, and they feel they learn three difficult subjects with completely different terminology, methods, and information at the same time.

As a practicing physics-chemistry teacher, I have an excellent opportunity to hands on study these issues and exploit the possibilities. In order to resolve the aforesaid issues, I developed a teaching method and gave recommendations that allow teachers to avoid unnecessary repetition by using a well-organized curriculum, themes, and by paying attention to the overlaps. As a result, a spiral curriculum teaching approach is implemented. By exploiting the common topics between the subjects, the students' complex science approach and correlation of scientific knowledge are shaped, and the work of other science teachers are supported.

Particularly, there are many correlations in material science and modern physics that includes particle theory, properties of material phases, properties of gas and gas particles, chemical effects of electrical currents, and atomic structures. In my Ph.D. dissertation, I show the usefulness of these topics to students by approaching them from either the chemist or the physics point of view.

The corresponding reference for this thesis is in [4].

Thesis 2.

I showed how to introduce science and scientific approach to students in lower classes with minimal physics background through simple experiments to raise and keep their interest toward science.

In physics and chemistry along with the overlapping contents the scientific approach, methods, and tools are also common. I showed modules that can facilitate the science learning curve of students when used consequently during classes. These methods and tools are independent of a specific class and appear in each science related subjects. Unfortunately, in students' mind these common themes and methods are separated. Therefore, they do not think that one approach learned during one class (experiment preparation, graphical data representation, etc.) can and should be used in a different class as well.

I developed and practically implemented a method that shows students the natural science-approach and its tools at various level. My method for younger students requires only few materials and basic items and includes experiments and derivation with a minimal physics background (free fall experiment, Galileo ramp measurements, investigation of various effects on the period of a harmonic oscillator, calibration experiments). For older students with more physics background and abstraction level my method includes theoretical derivations, comparison of measured data, and simple theorizing. As an example, I use the derivation of constant acceleration motion and the calculation of the molar heat capacity of ideal gas at constant volume. In addition, I study how to discuss those aforementioned simple experiments in depth with older students.

Thesis 3.

I showed the efficient use of the computer to introduce the natural science approach and for scientific applications. I carried out several computer analysis of physic and chemist experiments with students, and I developed a method to solve a certain type of computational exercise using a computer.

Students, under my guidance, used a computer software named WebCam Laboratory (recently LabCamera) to analyze experiments for a physics competition. Our goal was to avoid the use of the computer and the software to be an end in itself. We chose certain kind of experiments that provides different or additional results by using a computer than by the traditional observation methods. Most of the experiments are interdisciplinary, for example determination of the viscosity of glycerin and measurement of the femoris muscle strength. The students were able to use the advantages of the computer based observation and analysis at various scientific area.

In my experience, Microsoft Excel is an excellent tool to not only process and represent experimental results during the teaching of physics and chemistry, but also to solve calculation problems in reasonable cases in physics and chemistry. In general, practical and recommended cases to use Microsoft Excel are the verifications of the algorithmically solvable standard exercises. It can be used for batch processing to simplify calculation and to reach a complex general conclusion. I proved the applicability of this method in two detailed examples. One task is the calculation and the discussion of the gravitational force on the planets of our solar system. The second task is the calculation and comparison of the specific heat of saturated carbohydrates. Both of the exercises were completed by students and their opinions were surveyed.

The introduced method is also applicable to help the teachers' work to easily determine the results of various standard tasks and to frame tests (for parallel classes and for A, B and C groups).

The corresponding reference for this thesis is in [1].

Thesis 4.

I developed and executed an extracurricular activity program to process various complex interdisciplinary natural science topics. I showed these themes are capable to awaken the interest of students, and the extracurricular class tested methods help students to prepare for individual work as well as for various topic processing.

I had an intuition already during my first year of teaching to create a "Complex extracurricular activity of science" course. I worked out the main goals and syllabus of the course and offered it for 10^{th} and 11^{th} grade students. My aim was to discover together with the students the colorful nature, to astonish its beauty and system, while finding the overlapping points in the syllabus of various natural science subjects. It was an important goal to study some natural phenomena in the physics, chemistry, and biology point of view, and to discuss the theoretical background of these in more detail than in a regular class. As an example, researching the natural occurrences of various phenomena learned during the regular curriculum. In addition, my goal was to give an insight to students about scientific research, gain knowledge about various research methods that could be the base of their future research work.

During the upcoming years, the syllabus of the course continuously evolved and advanced, its goals and purpose were crystalized. While the new students in each year provided the uniqueness and renewal of the course, we always adjusted the various projects to the students' interest or to relevant topics. In addition, student presentation of projects provided new insight for each theme.

During the first few classes of the course, I presented various themes in a form of a presentation to give an example to students about how to work out a theme by the complex science approach. After that, the students chose projects from the above-mentioned syllabus from which they want to learn more in a form of teacher presentation followed by a guided discussion. From time-to-time, teacher presentations were replaced by student presentations based on chosen projects and self-guided research.

The syllabus of the course and the developed themes could inspire other teachers for similar courses, and might help them to choose topics and to hold the extracurricular activities.

The corresponding references for this thesis are in [5-7].

Thesis 5.

I developed a miniseries that compounds natural science themes and implemented it with one of my college's help. I showed that this series is capable to increase the interest of students with various age, and to encourage them for higher-level education in science and technology.

During the academic year of 2013-14, along with the help of my college, I provided a highly successful natural science miniseries for our students named "Premistry". The goal of this series was to increase the popularity of science classes, especially physics and chemistry, among our students. The goal for younger students was to introduce and endear natural science, and for older students to help their carrier choice and to understand and correlate things in depth.

The series was constructed from three teacher presentations and three laboratory sessions. At each occasions we chose topics that related to multiple subjects. As a result, we increased the popularity of more than one subject at the same time, as well as developed and deepened the integrated science approach. The students were able to experience that to understand a natural or an everyday phenomenon and experiment, the knowledge of multiple subject and the combination of them is necessary.

For the Pemistry events, a large number of student signed up and participated also. The presentations were in front of a full house, and there were overflow for all the experimental sessions. Each time, the number of participants increased as Premistry advertised itself. It was not necessary to reward students; they realized that by participating on the event is the price itself.

The enthusiasm and interest of students toward science were increased after the Premistry events. It was observable that the activity of those students who participated on the event increased during regular class sessions and had good comments during the class. Many times, they were able to use the knowledge learnt at the event on regular classes.

The corresponding references for this thesis are in [2-3].

Thesis 6.

I showed that teaching physics and chemistry subjects using the complex science approach and drawing the students' attention to the overlap between various subjects are effective in other area of talent developments such as competition preparation.

During my career, I trained many students for various competitions. In all cases, the similarity during the preparation phase was that they gained such knowledge and skills that without the competition they would not have been able to learn.

Here, I focus on such competitions in which name's include the interdisciplinarity of science or my students reached good places because they were prepared in that sense.

My students won or ended up in the top ten on the finale of the following national completion: Integrated Science Competition, Avram Hershko National Science Competition, Karoly Irenusz National Physics Competition, Gyorgy Olah National High School Chemistry Competition, and Denes Gabor Scholarship. Students were prepared to these competitions not only by myself but also by some of my colleges.

The usefulness of the interdisciplinary approach and method showed two main modes during the preparation for competitions. First, I was able to introduce the overlap between the knowledgebase of subjects necessary for competitions. I was able to discuss the various phenomena by connecting them to the information originating from different subjects. Second, students received assignments during the completions to work at home (poster, video, essays, etc.) which required connecting various subjects. It was not a problem for students to think interdisciplinary after several years of work with them in similar approach.

Thesis 7.

I developed a method how to use projects about interdisciplinary science themes as well as showed its success such as an increase of the interest of older students who are not motivated toward science classes.

Projects are an excellent way to study interdisciplinary themes. The method can be used in multiple situation and with various groups such as extracurricular activities, in elementary school setting, as an elective course, or during science classes in senior year for those students who do not attend elective courses. The goal of the method can be various based on the previous circumstances: deepening the students' knowledge, increase social competence, develops learning skills, or to increase motivation.

Sad, but it is true and needs to be addressed that most of the students lost interest toward science toward the end of high school years. I developed and successfully used with these students the project-based interdisciplinary method to motivate and increase their interest in science. Students worked in groups and researched various interdisciplinary themes selected by me. The groups had to prepare an abstract and a presentation that were presented in front of their peers. The presentations were followed by discussion and evaluation.

Thesis 8.

I developed the concept of an interdisciplinary synthetic science course or module for high school seniors to organize the knowledge they learned during physics, chemistry, and biology courses over the years.

In my experience, many science teacher does not like the fact that after students graduating from high school, most of the knowledge and approach taught during the years are wasted (many times only seemingly, but most of the case literally), and are not used in the course of the students future life. This issue also concerns many people even without any science background, but with great commitment toward education and the future of the students.

Conserving the science knowledge and approach could be possible by an interdisciplinary synthetic science course or module. I developed goals, organizational possibilities, and syllabus of such a course. I studied and presented the possible questions, issues, and objections, as well as provided the answers to resolve them.

Thesis 9.

I created simple research projects and worksheets for elementary and high school students that allow them to use scientific principles and practice.

In my experience, many students arrives to a conclusion that the knowledge learned during physics and chemistry classes are only part of those fields with their abstraction, closed terminology, and symbols. They think that knowledge has nothing to do with the phenomenon in everyday life and basic principles.

In order to avoid and disproof this incorrect thoughts, we usually show examples from everyday life and from the nature that relates to the given material and principles. I think there is another possibility to show students that physics and chemistry class knowledge are closely related to everyday life. This route uses project works that are based on everyday phenomena, materials, and items, and to understand them a scientific approach is necessary. As a result, the students become part and in control of scientific research.

I developed, implemented in practice, and showed in my Ph.D. dissertation two examples to support the previously mentioned method. The work contains worksheets for students and answer sheets that are the instructor version of the test sheets. In addition, I prepared methodology guidelines, a list of recommendations, a catalog of the necessary items of the experiments, and suggestions for the preparation and process of the research. One test sheet closely relates to the curriculum, it helps to understand and deepen the knowledge about the density of ideal gas, the other sheet circles a chemistry myth: “Can I eat Mentos after drinking coke?”

Application of results and future work

My results, shown above and in more depth in my Ph.D. work and publications, are intended to aid high school level physics and chemistry teaching. As a practicing physics-chemistry teacher, I have an excellent opportunity to study both subjects at the same time, and to share my own experiences and technical knowledge with my colleges who are teaching a different subject along with one of these.

The methods, worksheets, syllabus of extracurricular activities and mini courses were worked out over the progress of several years. I developed and adjusted them based on my personal experiences. I tested all methods, described in my Ph.D., several times on students, and I am using them successfully during my classes throughout my teaching years. As a result, my students are able to link the knowledge of various subjects, and these methods and activities are capable to motivate them. Those students who were thought using these methods and participated in these courses were successful during their studies, many of them chose science and technology field for their major at universities, and some of them reached excellent results on national competitions and during the higher-level education.

My results, methods, worksheets, extracurricular programs, and themes are able to support any high school physics and chemistry teachers to reach the above-mentioned goals. In my Ph.D. dissertation and publications, I introduced the methods and practical exercises in depth, so they could be directly utilized to aid my colleges.

I would like to continue my technical methodology research in the future. As a practicing teacher, the continuous experiences lead me to the more detailed list of the overlap of physics and chemistry subjects that I am planning to publish and present for practicing teachers to help their work.

In our changing world where the background, the interest, and the talents of high school students are ever-changing along with the frequent renewal of the public-school curriculum, this kind of research is not only justified but also necessary.

Publications connected to the theses:

[1.] **Szakmány Csaba**: Microsoft Excel program használata a természettudományok tanításában; *Fizikai Szemle* 2018/3., pp. 95-100.

[2.] **Szakmány Csaba** – Rákóczi Melinda: „Premistry" természettudományos népszerűsítő sorozat Első rész; *Magyar Kémikusok Lapja* 2018/4., pp. 128-131.

[3.] **Szakmány Csaba** – Rákóczi Melinda: „Premistry" természettudományos népszerűsítő sorozat Második rész; *Magyar Kémikusok Lapja* 2018/5., pp. 166-171.

[4.] **Szakmány Csaba**: A kémiatanár méltósága és felelőssége a diákok anyagszerkezeti ismereteinek kialakításában; *Középiskolai Kémiai Lapok* 2018/1., pp. 57-71.

[5.] **Csaba Szakmány**: Luminescence in Nature and in the Education; *Physics Competitions* Vol. 15 No 1 & 2 2013.
http://wettbewerbe.ipn.uni-kiel.de/ipho/wfphc/data/journal/PhysicsCompetitions_Vol_15_No_1u2_2013_09.pdf
(Last visit: 23. 06. 2018.)

[6.] **Szakmány Csaba**: Lumineszcencia a középiskolában. In: TASNÁDI P. (szerk.): *Természettudomány tanítása korszerűen és vonzóan*. ELTE TTK, Budapest, 2011., pp. 289-294.

[7.] **Szakmány Csaba**: Kolloidok körülöttünk – Ötletek a kolloidok tanításához. In: TASNÁDI P. (szerk.): *Természettudomány tanítása korszerűen és vonzóan*. ELTE TTK, Budapest, 2011., pp. 546-550.