European Commission

Portfolio 1

Dealing with high achieving students in non-formal science education

examples of best practice

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DiSSI Diversity in Science towards Social Inclusion

Univerza v Ljubljani

Contents

ACTIVITIES FOR THE GIFTED AND TALENTED STUDENTS IN CHEMISTRY

National perspective

Guidelines for working with gifted and talented students in Slovenia were published by the Ministry of Education and Sport in the White Paper on Education in the Republic of Slovenia in 2011. In the chapter of Mojca Juriševič entitled "Gifted Education" the Slovenian perspective is illustrated. The awareness of the importance of education of gifted students and the national interest derived from it determines today in different countries the most important guidelines of educational policy when defining giftedness in the educational context. The definition of giftedness largely determines the methodology for identifying gifted students and the strategy for working with them in school. The concept of inclusion of the gifted, which was developed in parallel with special education, is today the predominant orientation of contemporary schools, which, on one hand, provide respect for the rights of gifted students by adapting teaching to their needs and, on the other hand, draw attention to the assumption of responsibility for their own learning and knowledge, thus creating not only personal but also wider social benefits, since "... the gifted students of today are the social, intellectual, economic and cultural leaders of tomorrow and their development cannot be left to chance". After a detailed analysis of the identification of gifted and talented students, including at international level, the author proposes some solutions. The first proposals concern the identification of gifted students, in particular we must follow the definition of who the gifted students are. Gifted students perform well above average and belong to the top 10% of the population. Their outstanding talent is judged on the basis of their intellectual abilities, their creativity, their academic performance (in languages, mathematics, humanities, science, technical subjects), their artistic performance (music, art, performing arts, literature) and their sporting achievements. In the second part, the proposals attempt to illustrate the pedagogical adaptations to meet the needs of gifted children. The aim of the organizational adjustments is to modify the school obligations for reasons of the gifted student's possible absence from regular classes due to his or her extracurricular activities related to his or her giftedness, e.g. absence due to training, workouts, competitions or obligations in other educational institutions, provided that these provide the gifted student with better working conditions than the home school and the scope of the regular curriculum of school education in individual school subjects. The aim of the content offers is to adapt the teaching contents and methods to the development of the gifted students' thinking, learning strategies, knowledge and interests and to promote their motivation to learn, whether in the form of internal, flexible or partly external differentiation or in the form of modified individual and group activities within the extended school program (additional lessons, preparation of competitions, research camps (informal chemical education), personal development programs, excursions, projects, art colonies ...). Other types of activities can also be created if they are appropriate for a single gifted student, e.g. subject or class acceleration. An important aspect of proposals for support solutions is also the partnership between different institutions - schools, families, the local community and/or other organizations and institutions (sporting, cultural, technical, etc.) - or universities in the formulation and implementation of individualized programs for gifted students, in order to relieve teachers and gifted students of the burden of time-consuming and overlapping content; furthermore, adaptation programs should also be more meaningful and vital (e.g. calls for projects).

Chemical competition for gifted students

Every year in Slovenia, chemistry competitions are organized for lower and upper secondary schools. The competition is organized by Zveza za tehnično kulturo Slovenije (ZOTKS) in cooperation with Slovenian Chemical Society the University of Ljubljana, the Faculty of Education and the Faculty of Chemistry and Chemical Technology. The purpose of the national chemistry competition is:

to broaden and deepen the chemical knowledge of lower and upper secondary school students beyond the regular chemistry curriculum,

- Popularization of chemistry,
- the application of knowledge of chemistry,
- the comparison of the chemical knowledge of students in secondary education,
- Identification and promotion of gifted students at secondary level I and II in chemistry,
- Motivation to further deepen your knowledge of chemistry,
- Sensitisation of secondary school students to the importance of understanding nature, its processes and laws and of protecting nature and the natural heritage.

With good performance students can earn additional points for the Zois Scholarship for Gifted Students and, in special cases, points for entry into secondary school.

Research projects with researchers at institutes and universities

Some chemistry teachers in lower and upper secondary school act as mentors for students in conducting research work in chemistry. These students can also enter the Slovenian Chemical Institute, Josef Stefan Institute or different Faculties in the University of Ljubljana for conducting research in professional laboratories. Researchers in these institutions are out-of-school mentors for students. The research is than presented by the students and evaluated.

Specific example: In view of the daily production of several tons of different waste, it is important that we look for new ways of processing this waste and educate future generations about the importance of reusing waste materials. 70 high school students from the BIC Ljubljana were involved in research on understanding green chemistry, extraction of essential oil and its properties, pectin isolation and microencapsulation. The research included testing and optimisation of different types of pectin isolation, microencapsulation, essential oil isolation, etc. After the experiments had been developed and optimized, we prepared a workshop for high school students in which we tested their understanding of selected learning contents with a knowledge test. The results obtained show that the strength of pectin microcapsules is better when the mixture representing the liquid core is more viscous. In a late knowledge test it was also found that the students in the experimental workshop acquired adequate knowledge about the isolation of components from apparently useless citrus peels. We presented our research work with a poster presentation at the international conference Slovenian Chemical Days 2020, which took place in Portorož, Slovenia. Talented high school students who participated in the research were awarded the Slovenian Pharmaceutical Company Krka, d.o.o. award.

Elective topics in chemistry- Lower Secondary Education

Experiments in Chemistry

The elective subject Experiments in Chemistry refers to the compulsory subject Chemistry in the 8th and 9th grades and to the subject Natural Sciences in the 7th grade. It is aimed at students in the 8th and 9th grade and comprises 32 to 35 hours each. The aim of the course is to deepen the students' knowledge in the above mentioned subjects, especially in the field of experimental skills and experimental procedure (making hypotheses, citing important observations and explaining them with conclusions). In the elective course "Experiments in Chemistry", the aim is to develop and deepen basic scientific education, the basics of scientific complex thinking, various skills and abilities and to combine theory and practice. Students learn to experiment, learn about the role of the experiment in science and learn to distinguish between variables and constants. They also go through the history of experimentation and the contributions of the most important chemists. They will be trained to understand and use symbols for labeling dangerous substances, R and S phrases, how to handle dangerous substances and how to store and dispose of them. A large part of the course is devoted to safety in the chemical laboratory. They go into detail about laboratory inventory, laboratory techniques and operation using an experimental approach. They are also tested on the construction and use of simple laboratory equipment.

Environmental Chemistry

In the elective course “Chemistry in the environment”, students deepen the knowledge acquired in the 8th and 9th grade chemistry course and the 7th grade science course. It is intended for 8th and 9th grade students and consists of 35 and 32 hours, respectively. The aim of the course is for the student to get to know the impact of people and themselvs on the environment. Students address real environmental problems which surround them on a daily basis. The teacher must decide with the students to discuss in detail one module related to the environment and environmental problems. The proposed modules are:

- Atmospheric processes and air quality,
- Inland and marine water quality,
- Soil and groundwater quality.

In the course, students learn to identify environmental pollutants and collect data on the quality of the environment, they also learn about the consequences of a polluted environment on human health, especially in their home environment.

The basic teaching method of the elective subject is experimental work. Students plan and carry out experiments to prove substances that may be contaminated with air, water or soil.

Chemistry in Life

The elective subject Chemistry in Life is taught in 9th grade and comprises 32 hours. It consists of three modules:

- Substance competition (Chromatography),
- A world without colors would be boring (Learning about natural dyes),
- Chemistry also smells (Essential oils).

In this course, students learn more modern techniques for separating mixtures and learn to recognize unknown substances. Great emphasis is placed on different types of chromatography (paper, thin film, gas), where they are accustomed to the safe conduct of experiments and learn the proper disposal of hazardous waste.

Environmental Education

The optional subject of environmental education is implemented in 7th, 8th and 9th grade. It consists of 35 or 32 hours. The aim of the course is to acquaint students with the environmental problems of our planet, and to encourage them to act actively and responsibly in the environment. The main idea of the course is education for a sustainable future. The main topics covered in the course are:

- The importance of water for the life of all living beings,
- The importance of air for the life of living beings and human health,
- The importance of energy for life (natural energy sources),
- The importance of soil for humanity,
- What is biodiversity,
- Connection between producers and consumers,
- Consequences of human intervention in the environment.

Elective topics in chemistry- Upper Secondary Education

There are 210 hours of compulsory chemistry program in the general grammar school. In addition, students can choose an additional 35 hours of elective program, the purpose of which is to deepen understanding, upgrade and acquire special skills.

The proposed optional content sets are:

- Selected examples from spectroscopy to determine the structure of organic molecules,
- Medications,
- Paints and dyes,
- Chemistry and food.

Depending on the interests of students and the school, the professional staff of chemistry teachers at the school can prepare a new proposal for an elective program.

Activities carried out at the KemikUm Center at the University of Ljubljana, Faculty of Education

The KemikUm Center, a development-innovation teaching laboratory, has been operating at the Faculty of Education in Ljubljana since 2017, the purpose of which is to contribute added value in the field of chemical education in Slovenia. The organization and implementation of workshops and events is based on the connection of the UL PEF study process with school practice and the popularization of chemical education among young people. In 2019, 489 primary school students from all over Slovenia and 44 future chemistry teachers, 28 future primary school teachers and 16 future preschool teachers experimented with gaining experience in conducting experimental work in connection with school practice. More information about the KemikUm Centre is available on the official website https://www.pef.uni-lj.si/kemikum.html.

Each year the KemikUm Centre also organizes other activities such as: teacher conferences, teacher seminars and closing events for chemistry competiton.

Chemistry solves crimes

This is an annual event taking place within the elective course "Science in forensics and sports" and is meant for primary school students. At the workshop, students are presented with a fictional crime scenario, on the basis of which they later collect and analyse evidence in the laboratory with various experimental techniques and experiments with the goal to either confirm or discard the guilt of our suspects.


(Students collecting crime evidence, KemikUm, 2019).

Chemistry is experimenting!

A traditional event where students from different primary schools carry out experimental work in the field of organic chemistry. All experiments are new and upgraded for students, so that they are also suitable for working with gifted students. They cover the context of life situations and the triple nature of chemical concepts n most cases, instead of hazardous chemicals, the experiments use a summary of substances from everyday life that are close to the students. In their experiments they are also supported by the preservice chemistry teachers, who make sure that the students collect the results carefully and formulate the observations and conclusions of the experiment they are conducting correctly.

(Future Chemistry Teachers presenting experimental workshop to students, KemikUm, 2018).

Molecular gastronomy

In this workshop, students learn about some modern food preparation techniques used in modern gastronomy and cuisine, and their chemical background. They learn about the influence of pH, enzymes and temperature on hydrocolloid gel gelation and do reverse spherification, fruit spaghetti, kiwi caviar, liquid nitrogen ice cream and chocolate espuma from the microwave.

(Students preparing fruit spaghetti and espuma, KemikUm, 2019).

KemikUm drives Methane

The workshop is intended for 9th grade primary school students, and focuses on the following learning objectives of the content set "Family of hydrocarbons with polymers": students learn about natural gas as a source of organic compounds (especially hydrocarbons) and a non-renewable energy source; students learn the basic properties of hydrocarbons, connect them with their use and safe handling; students distinguish between complete and incomplete combustion of hydrocarbons and students study the effects of the use of hydrocarbons and their derivatives on the environment.

The FIBONACCI project

The FIBONACCI project is intended for inquiry-based science lessons and is a continuation of the already completed POLLEN project. The project focuses on supporting teachers in the classroom. They organize workshops for teachers, the content of which is related to the curriculum and is intended for them to get to know and test modern approaches in inquiry based teaching of science. At the workshops, all the experimental activities that the teacher can then carry out in class are tested. Teachers can borrow experimental equipment. Teachers can also cooperate with other schools in other participating countries

The PROFILES project

The PROFILES project is intended for inquiry-based teaching and learning science subjects based on the socio-science context. Its goal is to increase the ability of teachers to develop a creative, problem-based and

socio-scientific environment, which should also be based on their wishes and needs. It is known that such learning situations stimulate students' motivation to learn science subjects. Of course, it is important to monitor both internal (students learn the importance of learning) and external motivation (students are encouraged to learn by teachers or teaching materials) of students to learn science content in all science subjects and at all levels of education. At the same time, these learning strategies would develop students 'competencies, such as the decision-making and problem-solving skills they face as adult citizens

In chapter 9 in the book „Teaching Gifted Learners in STEM Subjects" M. Juriševič and I. Devetak describe that Slovenia has a rich history of working with the further recognised gifted students as one of the groups of students with special needs, envisioning certain adaptations within the framework of the obligatory and extended curriculum, but these measures were not unified on a national level. Slovenia places itself amongst those European states that emphasise the principle of inclusivity in the education of the gifted, and that implement a 'mixed' approach: education of the gifted largely takes place in an integrated way within the framework of the obligatory and extended curriculum. The PROFILES approach – Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science – aims at disseminating Inquiry-Based Science Education (IBSE) by supporting science teachers in elementary and secondary schools to develop more effective teaching in innovative learning environments, focusing particularly on both the intrinsic and extrinsic motivation of students in the learning of science (M. Juriševič and I. Devetak, 2017).

Activities for gifted children carried out in some Slovenian primary and secondary schools

Primary and secondary schools in Slovenia do not have a unified plan of what activities for the gifted must be carried out, so each school decides in its own way. The activities of some randomly selected schools are presented below. The data about the activities for gifted students carried out on different schools is accessible on the school's official websites.

Elementary School Mladika

- Visit and workshops in the company Mikro + polo in Maribor (genetics, animal section, production of home cosmetics…),
- Workshops at school or camp (each workshop 2 school hours): chemistry experiments,
- Encourage students for research activities (seminar assignments; research assignments through ZRS Bistra Ptuj - especially 8th and 9th grade).
  The school officila

School official website: http://mladika.si/

Elementary School Marjana Nemca Radeče

- Debate club for gifted students,
- Encouraging tutoring, where they offer learning assistance to other students.

School official website: https://jzosmn.radece.si/

Elementary School Ljudski vrt Ptuj

- Additional lessons, research assignments, various projects, international cooperation, creative workshops for 4th, 5th and 6th grade students,
- Visit of the herbalist to Sv. Ani or Benedikt with the title We live with nature or a visit to the Ptuj Sports Center - Biotechnical School in Turnišče,
- Visit to the Krško nuclear power plant.

School official website: https://www.os-ljudskivrtptuj.si/

Elementary School Antona Žnideršiča Ilirska Bistrica

On Friday, September 29, 2019, students of the elective course Experiments in Chemistry and gifted students visited the Jožef Štefan Institute and the National Institute of Biology in Ljubljana as part of the Researchers' Night project. At the Jožef Štefan Institute, they first visited a glass-blowing workshop, where they design laboratory glassware, and then they were able to participate in experiments with liquid nitrogen.

School official website: https://www.o-azilb.si/

Elementary school Milojke štrukelj Nova Gorica

Activities offered for gifted students: chemistry slightly different:

- Chemistry workshops: conducting various experiments at school,
- Workshops outside the school: tour and workshops in Goriška Brda (lavender products),
- Visit to institutions, institutes: Agricultural and Forestry Institute Nova Gorica, Salonit Anhovo,
- Chemical news: a group of ninth-graders compile chemical news every other month and publish it on the school's website,
- Camp: Participation in the camp in Čepovan with chemical contents.

School official website: https://www.osms.si/

Tončka Čeč Elementary School

Execution of the project task: From waste to dessert. Green entrepreneurship. Organized workshops for students from 6th to 9th grade, where they made backpacks, reusable bags, cosmetics and the like. They then presented their products to the remaining students of the school on the stands.

School official website: http://www.os-toncke-cec.si/

International perspective

Chemistry Olympiad

The **International Chemistry Olympiad** is an annual academic competition for high school students. It is one of the International Science Olympiads. Slovenian secondary school students achieve high results every year (i.e. year 2019 all four secondary school students from Slovenia received bronze medals).

Students are prepared for the competition outside the school with mentors form the Faculty of Chemistry and Chemical technology.

Books and Journal publications about the gifted in chemistry

A review of the existing literature in the field of green chemistry and spectroscopy was made. It was found that many experiments have already been developed for the mentioned fields. Below you will find some weblinks to good examples. In the next phase of the DiSSi project, a set of experiments related to the content field of green chemistry and spectroscopy will be developed based on already known ideas for talented students.

https://www.science.gov/topicpages/g/green+chemistry+experiments

Science.gov is a gateway to U.S. government science information. The portal offers free access to research and development (R&D) results and scientific and technical information from scientific organizations across 13 federal agencies. Science.gov makes it possible for users to search over 60 databases, over 2,200 websites, and over 200 million pages of authoritative federal science information in many formats, including full-text documents, citations, scientific data supporting federally funded research and multimedia. On this website, we can find many experiments in green chemistry that are useful for talented elementary and high school students.

https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00375

Student-designed green chemistry experiment for a large-enrollment, introductory organic laboratory course. The article describes a 3-week module incorporating the principles of green chemistry which was developed for a large-enrollment, introductory organic chemistry laboratory course. An emphasis was placed on students planning their own experiments with the goal of obtaining a greener reaction (week 1). Students executed their designed experiments in week 2 and were given an opportunity to repeat the experiment or further optimize the reaction conditions to improve the yields during week 3. A postlab writing assignment as well as pre- and postsemester surveys were used to evaluate student learning and confidence. These data revealed an increase in students' understanding of green chemistry concepts as well as their confidence in their ability to modify a reaction to improve the results. We anticipate that this overall framework can be adapted to other large- and small-enrollment laboratory courses.

https://www.uu.edu/books/GreenChemistryLabs/

"Green chemistry labs" is a manual containing twenty-four (24) experiments targeted at the high school level of education. It was developed by Dr. Sally Henrie, Kacey Fowler, Ruth Hall, and Kimberly Lindsey at Union University over multiple years. Dr. Marlyn Newhouse and Prof. Carol Leslie also contributed to the project.

Take a look around this site to get a feel for what our labs are all about and find out if they're right for your classroom. The website includes (1) student's laboratory manual (pre-lab questions associated with the introduction and procedure; safety reminders included in the procedure text; helpful hints in the text; figures of the different apparatures and experiments covering additional concepts) and (2) teacher's manual (answers to pre-lab and post questions in text (not appendix); unified materials section with supplies indexed; large margins for note taking).

There are 23 different experimental concepts: safety, significant figures and measurements, density, separation of a mixture, physical and chemical changes, energy and calorimetry, electron configuration, UV spectrum, ions, molecular shapes and models, polar and nonpolar bonding, ionic and covalent bonds, types of chemical reactions, moles: Avogadro's number, periodic trends and uses, stoichiometry, properties of acids and bases, titration, oxidation-reduction, rates of reaction and kinetics, thermodynamics, gas laws and catalysts.

https://www.beyondbenign.org/lessons/introduction-overview-resource-guide/

"My Green Lab" is fundamentally and permanently improving the sustainability of scientific research. They introduce sustainability to the community responsible for the world's life-changing medical and technical innovations.

As a non-profit, they were formed to unify and lead scientists, vendors, designers, energy providers, and others in a common drive toward a world in which all research reflects the highest standards of social and environmental responsibility. Run "for scientists, by scientists," they leverage credibility and track record to develop standards, oversee their implementation, and inspire the many behavioral changes that are needed throughout the scientific community. Though My Green Lab focuses solely on laboratory environments, they believe that their activities will excite similar changes across other industries, and in the private lives of the millions of people who spend their time in labs.

https://pubs.acs.org/doi/10.1021/acs.jchemed.8b01009

A laboratory experiment was developed to introduce students to waste valorization. This is the process of reusing, recycling, or composting from wastes, useful products, or sources of energy. In this laboratory experiment, waste valorization is demonstrated through transforming waste orange peel (WOP) into a marmalade-type gel by extracting a pectin-based mixture (or sol) and forming a gel in combination with an acidified sugar solution. Upon isolating the pectin sol, students examined how the rheological properties varied as a function of temperature using capillary viscometry. Gelation was followed via rotational viscometry, and non-Newtonian, shear-thinning properties were demonstrated by monitoring the viscosity change as a function of spindle RPM. In addition to providing a safe and green alternative to the traditional borax-cross-linked poly(vinyl alcohol) gel for students to study, this experiment demonstrates that valuable products for everyday use can be created from household waste such as WOP. Students making the transition from a first to second year undergraduate chemistry program within a natural-sciences degree have successfully conducted this laboratory experiment.

In the next phase of the DiSSi project, a set of experiments related to the content field of green chemistry and spectroscopy will be developed based on already known ideas for talented students.

Literature review from "Spectroscopy" topic

http://www.kii3.ntf.uni-lj.si/analchemvoc2/file.php/1/analchemvoc1/slo/experiments.htm

Experimental approach to analytical chemistry for schools.

In various industrial activities more and more people of different professions are using analytical methods in their daily work. Students who are trained in vocational schools for chemical and related activities will

need even more knowledge and skills in analytical chemistry in the future, as employers expect them to do the same.

Vocational schools in different activities and countries do not have the same opportunities to teach analytical chemistry. They differ both in the equipment and in the amount of time their programs devote to laboratory work. This project offers a different approach to teaching and learning analytical chemistry by sharing experience through an experiential approach based on the introduction of new, low-cost teaching materials that can be easily transformed into various simplified analytical tools and shared by the partners. This approach will allow schools that do not have the appropriate professional tools to introduce practical aspects of analytical chemistry into schools and to develop experiments that are appropriate to their activities.

The target group of the project are professors, laboratory assistants and students of vocational schools who need the most experienced approach to analytical chemistry. The partners will identify gaps in teachers' knowledge of analytical chemistry and organize training in analytical chemistry with an experiential approach for the invited teachers in each country. The partners will support teachers in introducing these approaches into school practice and encourage them to develop their own innovative experiments. Students are encouraged to incorporate an experiential approach to analytical chemistry in their project work. A special website will be set up to collect and disseminate experiments among interested teachers. This collection of experiments that meet the needs of the individual activities will be one of the results of the project. The final result of the project will be a handbook for teachers that describes an experiential approach to learning the basics of analytical chemistry.

https://pubs.acs.org/doi/abs/10.1021/ed500731y

Introducing high school students to NMR spectroscopy through percent composition determination using low-field spectrometers-

Mole to gram conversions, density, and percent composition are fundamental concepts in first year chemistry at the high school or undergraduate level; however, students often find it difficult to engage with these concepts. We present a simple laboratory experiment utilizing portable nuclear magnetic resonance spectroscopy (NMR) to determine the percent composition in a series of household solutions explored with high school honors chemistry students. Students engage with the science by using a portable NMR spectrometer to acquire and process their own proton spectrum of rubbing alcohol. From the acquired data, students then used the aforementioned concepts and calculations to determine the percent composition of the mixture in wt/wt, and v/v percents. Students and teachers both expressed excitement with getting to work with “advanced” techniques and a better understanding of the relevance of stoichiometry, density, and percent composition.

https://www.tandfonline.com/doi/abs/10.1080/00219266.2001.9655774

High-school student research at Migal science institute in Israel.

Article presents the achievements of a programme at a research and development institute in Israel, where researchers in biology, biotechnology, agriculture, and chemistry supervised talented high-school students in performing research work and guided them in preparing individual matriculation projects. Not only did a number of the students' dissertations reach a level equivalent to a Master's degree and gain publication in

the scientific media, but almost all of them felt that this was the most meaningful school work that they had undertaken. Research scientists conducted scientific supervision, with pedagogical support from the Association for the Advancement of Science Education in Galilee. An important part of the programme is to familiarise students with the Internet and related multimedia and technology tools, as the medium for carrying out collaborative, interactive project-based learning. However, the main task is to prepare students to cope successfully with the explosion of information of our era. We teach them how to think, analyse, and access suitable information and use it to solve problems. This programme could be used as a model to enhance science education for other countries.

Literature review was also made for overlapping of the fields "green chemistry" and "gifted students". Namely, green chemistry provides an ideal opportunity for gifted children of any age to build critical and creative-thinking skills while also building skills in science, technology, engineering, and mathematics (STEM) areas. Exploring issues related to sustainability and environmental concerns permits gifted learners to identify problems, develop research questions, gather and analyze data, develop possible solutions, and disseminate this information to others. Green issues are especially appealing to gifted learners as they are sensitive to the world around them and often long to engage in projects that touch on issues facing their communities. The following results from the literature survey seem to be particularly interesting with regard to the project aims:

The paper entitled "Challenging gifted learners: General principles for science educators and exemplification in the context of teaching chemistry" by Taber, K. S. (2010) published in *Science Education International* pointed out that there is concern in some countries about the number of able young people entering degree level study and careers in physical science, including chemistry. Too few of the most talented young people are selecting "STEM" subjects to ensure the future supply of scientists, engineers and related professionals. The present paper sets out general principles to inform science teaching that will engage the most able learners, and hopefully encourage them to select science-based courses in higher education and aspire to careers related to science and technology. The nature of high ability and "giftedness" is briefly reviewed, and the educational needs of the most able students are considered. It is suggested that chemistry is particularly well placed to offer contexts, such as for example green chemistry, for the type of educational provision suitable for engaging and challenging the most able students, and examples of how the general principles recommended here might inform the planning of chemistry teaching are discussed.

Similarly, it has been pointed out by Hausamann, D. (2012) in the paper entitled **"Extracurricular science labs for STEM talent support"** that in the past decade, a growing lack of engineers, natural scientists, information technology experts, and mathematicians has been noted, especially in Europe. Corresponding to the need to attract young people to science and technology, numerous extracurricular science labs ("out-of-school labs") have been established. One of these initiatives is the DLR_School_Lab Oberpfaffenhofen, operated by Germany's national research center for aeronautics and space, DLR, and a typical example of such an out-of-school lab. It offers hands-on experiments for secondary-school classes, advanced teacher training and, as a special feature, enrichment courses for gifted students. One of the content areas, that students can target in the enrichment courses for gifted students, can be related to green chemistry issues. The article describes the concept behind the DLR_School_Lab, as well as the suitability of this lab to offer enrichment projects for talented school students. Other aspects discussed are its teacher education concept and the effectiveness of the concept of extracurricular science labs.

Further on, the paper entitled "Visual-spatial ability: Important in STEM, ignored in gifted education" by Anderson L. (2013) published in Roeper Review presents a visual–spatial ability as a multifaceted component of intelligence that has predictive validity for future achievement in science, technology, engineering, and mathematics (STEM) occupations. Although identification and development of STEM talent is a national priority, visual–spatial ability is rarely measured and relatively neglected in gifted education. Quantitative and verbal reasoning abilities are favored over nonverbal abilities in talent searches and gifted programs, which causes some high-spatial, gifted students to be overlooked. Creative production in STEM contents, such as creation of inovative solutions related to green chemistry issues, requires visual–spatial ability, and this ability must be developed in gifted education. Theories of intelligence and testing have advanced to provide methods for identification of specific cognitive abilities, such as visual–spatial ability. However, for these students to be successful in gifted programs, gifted-education services must be modified to accommodate gifted spatial learners and develop spatial talents.

The study entitled **"Learning environment for the gifted—What do outstanding teachers of the gifted think?"** by Miedijensky, S. (2018) published in Gifted Education International on the other hand, aims to assess the views of outstanding teachers of the gifted regarding their students' learning environment. Thirty teachers were interviewed and an interpretive approach was used to analyze their views. The teachers' comments were divided according to the following themes: (a) characteristics of gifted students, (b) characteristics of teachers of the gifted, (c) physical characteristics and population, (d) learning atmosphere, (e) emotional and social aspects, and (f) suitable curriculum and teaching strategies to meet the academic needs of the gifted. The study highlights the significance of exploring teachers' perceptions regarding the learning environment for the gifted in order to understand in depth what characterizes these particular teachers and to suggest an appropriate pedagogy that will enhance the students' giftedness. This study can contribute to teachers' training programs and curriculum design for gifted students and ultimately benefit all students.

In the article entitled "Real engagement in active problem solving (REAPS): an evidence-based model that meets content, process, product, and learning environment principles recommended for gifted students" published in APEX: The New Zealand Journal of Gifted Education the authors Maker, J, Zimmerman, R, Alhusaini, A. (2015) present a discussion about the teaching and learning models. It is described as what they believe is an exciting new model that can be used effectively in the teaching of gifted students. The main focus of the article is on the evidence showing that it is comprehensive (i.e., it is a way to implement all the curriculum principles important in teaching gifted students), flexible (i.e., can be used with a variety of ages of students, in a variety of settings, in many cultural contexts, and in many types of programmes) and valid (i.e., it has a research base showing that it has been developed using appropriate methods and is effective with all students, especially those who are gifted).

The paper entitled **"Designing challenging science experiences for high-ability learners through partnerships with university professors"** by the authors Newman, J. L., Hubner, J. P. (2012) in Gifted Child Today describes a Summer Enrichment Workshop (SEW). SEW is a 3-week enrichment program held at The University of Alabama (UA) Tuscaloosa, Alabama, for students identified as gifted and talented. The faculty of the College of Education, Program of Gifted and Talented (GT), formed a partnership with a College of Engineering faculty member who mentored the graduate student GT interns to develop and

teach middle school science minicourses in the SEW program. Data indicate that the challenge level of the science middle school minicourses improved and interns experienced more competence and confidence in teaching upper-level science courses. Contributing factors included having a science expert to collaborate in planning content and coteaching lessons; consistent reflection on practice; making learning more real-world; providing support, assistance, guidance and counseling; long-term planning; problem solving and inquiry; experimentation and risk taking, followed by immediate corrective feedback. The green chemistry issues seem to fit into most of the above mentioned cathegories interesting for the high-ability learners.

In the Journal of Advanced Academics, the paper entitled **"The effects of a science-focused STEM intervention on gifted elementary students' science knowledge and skills"** was published by Robinson, A., Dailey, D., Hughes, G., Cotabish, A. in 2014. Authors claim, that in order to develop Science, Technology, Engineering, and Mathematics (STEM) talents, education has to begin early. In this randomized study, the authors document the efficacy of teachers' professional development and a rich problem-based inquiry curriculum to develop the science talent of elementary students. The intervention, STEM Starters, a federally funded Jacob K. Javits project, provided sustained and embedded professional development to classroom teachers and to pull-out gifted program teachers to support the implementation of a problem-based curriculum in their classrooms. During the intervention, randomly assigned teachers participated in 120 hours of professional development that focused on science content, inquiry-based instruction, technological applications, and differentiated instruction within problem-based curriculum units. Statistically significant gains in science process skills, science concepts and science content knowledge were found among gifted students in the treatment group when compared with gifted students in the comparison group.

Authors Schroth, S. T., & Helfer, J. A. (2017) pointed out in the paper entitled **"Gifted & green: Sustainability/environmental science investigations that promote gifted children's learning"** which was published in Gifted Child Today, that the environmental studies provide an ideal opportunity for gifted children of any age to build critical and creative-thinking skills while also building skills in science, technology, engineering, and mathematics (STEM) areas. Exploring issues related to sustainability and environmental concerns permits gifted learners to identify problems, develop research questions, gather and analyze data, develop possible solutions, and disseminate this information to others. Green issues are especially appealing to gifted learners as they are sensitive to the world around them and often long to engage in projects that touch on issues facing their communities. Although the relevance to STEM subjects is clear, green investigations can also build skills across the content areas, in diverse subjects such as English/language arts, social studies, music and art. A variety of resources, including national and Common Core State Standards, exist that can help parents and teachers create investigations for gifted children that permit them to be both gifted and green.

In the Journal for the Education of Gifted Young Scientists (https://dergipark.org.tr/en/pub/jegys) founded in 2013 and published by Genç Bilge Yayıncılık (http://jegys.org/) in its 4 issues per volume, it can be found that seven papers are discussing chemistry learning, but only one directly focused on gifted learners, but some activities that are described in other papers can be adapted to the gifted in chemistry (i.e. CLIL method, multimedia problem solving…). However, Mohammad A. Chowdhury in his paper entitled "**Gifted Education in Science and Chemistry: Perspectives and Insights into Teaching, Pedagogies, Assessments, and Psychosocial Skills Development"** published by Journal for the

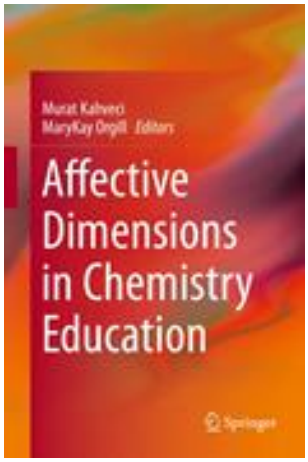
Education of Gifted Young Scientists in 2016 provides gifted education perspectives and creative insights with a particular focus on chemistry and science, and discusses associated teaching, learning, pedagogies, curriculum developments and assessments in the context of gifted education. The article emphasizes the cluster grouping approach, hidden curriculum, mentoring and proper counselling provisions in school that may significantly impact on gifted students' developments. The article discusses gifted students' psychosocial skills development to achieve their eminence. The implicated issues surround the development of psychosocial skills are discussed. The article sheds light on the cultural aspects of gifted education as the gifted students representing diverse cultural backgrounds encounter cognitive conflicts which affect their science learning and psychosocial skills development

The paper entitled »**Gifted Education in The Enabling Sciences With a Particular Emphases On Chemistry**« also by Mohammad A. Chowdhury published in Malaysian Online Journal of Educational Sciences in 2017 represents a review about education of gifted students in chemistry. This paper provides syntheses and critical analyses of literature, creative insights, fruitful information, and reflections on gifted education perspectives. It discusses the issues particular focused on chemistry. The gifted students' chemical misconceptions, and a range of educational approaches to resolve these misconceptions are discussed. The paper emphasized the development of psycho-social skills that enables the students to gain success and eminence as it is the ultimate goal of giftedness and gifted education. The implications of cultural issues on the development of students' psycho-social skills are also analyzed. The mental rotation and spatial ability that significantly affect the students in their developments of expertise and gain success in the sciences, are illustrated. The interrelationship between the mental rotation/spatial ability and the development of knowledge/skills in science are discussed.

In the paper entitled "**Interactions of chemistry teachers with gifted students in a regular high-school chemistry classroom**" by Naama Benny and Ron Blonder published in Chemistry Education Research and Practice in 2018. Regular high-school chemistry teachers view gifted students as one of several types of students in a regular (mixed-ability) classroom. Gifted students have a range of unique abilities that characterize their learning process: mostly they differ in three key learning aspects: their faster learning pace, increased depth of understanding, and special interests. If gifted students are to develop their abilities and potential, and learn optimally in a regular classroom, the teaching must be adjusted to meet their special needs. Chemistry high-school curricula in Israel have built-in potential to cater to the special needs of gifted students. Chemistry learning entails laboratory work and comprehension of abstract concepts and the interactions between teachers and students can trigger meaningful learning. Authors studied the interactions between teachers and gifted students in a regular chemistry classroom. Two specific categories of interactions with gifted students were identified during chemistry teaching: (1) interactions involving laboratory work and (2) interactions involving the challenge of teaching chemistry content. They concluded that since gifted students master abstract chemistry concepts quickly and with minimum scaffolding, no interactions regarding this aspect were reported. This study indicates the essential need for enhancing chemistry teachers' knowledge regarding teaching gifted students, especially how gifted students learn in general, and how to adapt this to the chemistry teaching both theory and laboratory skills according to the academic and curricular needs of the gifted students.

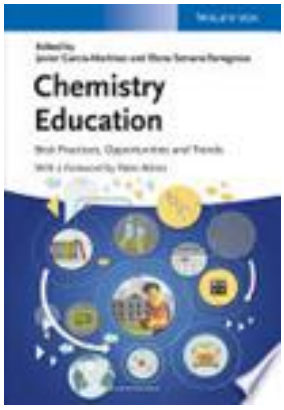
In the paper entitled "**Chemistry for gifted and talented: on-line course on Talnet**" by Hana Böhmová and Milada Roštejnská, published in Problems of education in the 21st century in 2009 authors describe

the education of the gifted and talented children, as potential contributors for the whole society, is emphasized and actively supported in the educational policy of the European Union. They present the project "Talnet – Online to Science" originated in Czech Republic is one example of a wide scale of extracurricular activities focused on the education of the gifted and talented. The methods used in Talnet are based mostly on the interaction of the experts with the children, primarily in the on-line "T-courses". The paper describes the structure, content and results of a two-semester on-line course "Biochemistry and Natural Compounds" that integrates the problem solving method with the home-made chemistry experiments in the form of an e-learning course. About ten talented high-school students from Czech and Slovak Republic participated in the first semester of the course. According to the evaluation results, the students find the course interesting and enriching. Four final theses were written and will be defended; one of them is intended to be applied for the national Contest for Young Scientists.



In the book chapter published by Springer in 2015 entitled "**Affect and meeting the needs of the gifted chemistry learner: providing intellectual challenge to engage students in enjoyable learning**" Keith S. Taber describes the chemistry learner in the lens of giftedness. Meeting the needs of gifted learners is normally considered from a cognitive perspective – a matter of incorporating sufficient higher-order cognitive tasks in learning activities. A major problem in the education of gifted learners is lack of challenge, which is needed to ensure such students are able to make progress. Lack of challenge can also influence learner motivation, and even lead to boredom. Meeting the needs of gifted learners is therefore a matter of matching task demand to their abilities to meet their emotional as well as their cognitive needs. The present chapter suggests that an aim in teaching should be to engage learners in activities that offer an experience of 'flow', which is achieved when learning demands offer sufficient, but not insurmountable challenge. Flow is an inherently motivating experience but requires a suitably high level of task demand to maintain deep engagement. The chapter draws on an example of a science enrichment programme that offered activities that were demanding for the 14-15 years old learners because they drew upon cognitively challenging themes (related to aspects of the nature of science), and required a high level of self (or peer) regulation of learning to provide high task demand. An example of one of the activities, concerning the role of models in chemistry is described. Students recognized that learning activities offered greater complexity, open-endedness and scope for independent learning than their usual school science lessons. The features that students reported in their feedback as making the work more challenging also tended to be those they identified as making the activities enjoyable.

The 5th chapter titled "Working with gifted science students in a public high school environment" written by M. Ngoi and M. Vondracek from the book **Science education for gifted students (2005)** describes the Chemistry/Physics Program at Evanston Township High School. It was designed in 1952 with the intention to provide the most advanced and motivated science students with a challenging college-preparatory science experience. A combination of independent studies, extracurricular academic competitions and independent science research projects to keep their gifted students in the Chemistry/Physics Program continuously challenged and motivated. Approximately 95% of all graduates who have taken the Chemistry/Physics Program have reported in surveys that they definitely feel better prepared for college and careers not only because they had college-level material in high school, but also because of the study and time management skills the developed by taking on multiple challenges that were offered outside the curricula.



The 28 chapters (792 pages) in the book include topics such as undergraduate chemistry curriculum, life-long learning, research-based teaching strategies, service learning, chemistry apps, and language in chemistry education.

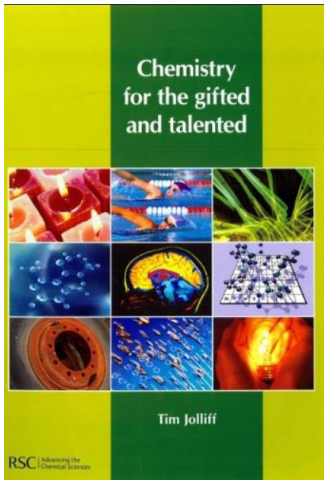
Similar to both volumes of Chemists' guide to effective teaching, 1, 2 chapters discuss larger issues related to student learning (e.g., Chapter 8, on problem-solving; Chapter 15, on concept integration; and Chapter 17, on the role of language), but then there are also chapters about specific teaching strategies and tools (e.g., Chapter 13, on flipping the classroom; Chapter 18, on effective use of demonstrations; and Chapter 26, on tools for blended learning).

The diversity of the authors of this text is appreciated. Forty-six people from 14 different countries and five continents have contributed to it. The variety of examples and experiences makes the volume accessible to the global chemistry education community.

The authors of most of the chapters mix the research literature with personal work and experiences from their schools or courses; this provides a strong, clear argument that also makes the topics relevant and achievable for any chemistry educator. Renée Cole provides a great overview of how research can improve teaching practices, describing many strategies supported by research as effective. Brian Coppola's discussion on authentic learning experiences is quite interesting, and I appreciate Hans-Dieter Barke's chapter on misconceptions with his distinction between preconceptions and school-made misconceptions. Keith S. Taber provides a great discussion of conceptual integration and its impact on both the understanding and teaching of chemistry. I also thought Cathy Middlecamp's chapter makes a strong case for chemistry educators' responsibilities to all students and not just future chemists. There are other good chapters that would be helpful for implementing a specific change (Chapter 13 if someone is thinking about flipping a class, or Chapter 14 if someone is interested in service learning).

Other chapters would be great starting points for larger conversations with colleagues about approaches to teaching students, course curricula and purpose or program curriculum.

The most important chapter for this project is the Chapter 19 entitled "Chemistry Education for Gifted Learners" by Manabu Sumida and Atsushi Ohashi. The authors describe the importance of chemistry and its development in the twentieth century. Chemistry has progressed with crossing interdisciplinary borders of physics and biology. From the analysis of the Nobel Prize in chemistry from 1901 to 2012 in this study, it was clear that the center of chemistry research is spreading worldwide and the researches are being conducted collaboratively in this century. On the other hand, students' images of chemistry are not necessary reflected on the progress of chemistry. There are various programs in chemistry education for gifted learners both in formal and informal settings. In formal settings, a kind of "acceleration program" for gifted education is getting popular. This is known in the USA as Advanced Placement (AP), which allows such learners to take university units in high schools. For related opportunities outside schools, there are many "enrichment" programs such as international science camps and contests. However, to consider the giftedness from a domain-specific perspective is just emerging, and there has been very little study about giftedness specific to "chemistry." This chapter outlines the characteristics of gifted learners in science, different modes of identification of gifted students in science, ideas of designing chemistry programs for gifted learners in the formal and informal settings. It also discusses about the effects of different levels of special science programs on gifted students and regular students, and implications of chemistry education for the gifted.



The book **Chemistry for the gifted and talented (Tim Jolliff, 2007)** is a refreshingly challenging educational book containing a wide range of differentiated activities for use in school and college. It includes an overview of the types of additional and alternative learning experiences that students can benefit from.

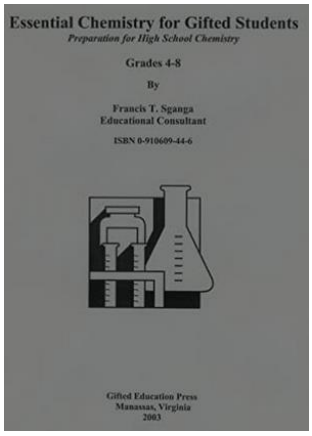
The main purpose of this publication is to provide resources and ideas for classroom activities that might be used as differentiated tasks or whole class activities. Some of the teachers using this resource may be involved with chemistry provision for the very able beyond lessons, so it is worth considering what some of the opportunities might be outside of the classroom. Some of these are listed towards the end of chapter under the heading *Opportunities for gifted students.*

Many of these resources are designed to be an episode that could fit into a lesson on a regular topic. The resources are designed so that they can be used to differentiate for the more able in a class or, if appropriate, for whole class use. Differentiation can put extra demands on teachers' time in class so for every activity there is a discussion of the answers and issues raised that are appropriate for the students. The *Discussion* of answers sheets are written for the students and can be given to them to review their own work or as guidance to help peer review and discussion. Some of the activities are designed to develop study skills in a chemical context, concept cartoons, understanding of the nature of models in science etc.

Some of the activities are designed to develop critical thinking skills. Students are often aware that examination questions have clear cut definite answers which the question, if read carefully enough, will point them towards. They are expected to reproduce well rehearsed thoughts and arguments.

Here are also some personal reflections by the author (T. Jolliff):

- Avoid 'experiments to show...' where the student can already predict the outcome,
- set more open ended tasks and encourage a greater diversity of reporting methods,
- do more investigation work (with a sigh of relief that it is not coursework) where the students (and teacher) do not know what the outcome is,
- allow gifted students to learn more by discussion and less by writing,
- repeatedly ask students if there are other additional possible solutions when they have arrived at an answer,
- foster enquiry by asking what questions could be asked,
- adopt a must, should, could model in the scheme of work which gives examples of relevant extension and enrichment activities,
- use more of the problem solving activities.



The book **(Essential chemistry for gifted students: preparation for high school chemistry (Frank Sganga, 2003))** is a remarkable hands-on-science book for gifted students. Sganga has provided them with an advanced differentiated curriculum in a challenging and stimulating format.

It includes seven chapters entitled:

(1) What is chemistry?

(2) Photosynthesis: the source of life,

(3) Grouping elements according to their characteristics,

(4) Hydrogen, carbon and the mighty little atom,

(5) All about chemical bonding,

(6) Solutions and

(7) Kinds of chemical reactions.

The book consists of several lab demonstration activities in such areas as oxidizing iron, electrical nature of elements, candle chemistry, solutions that conduct electricity, and double-replacement reaction.

Emphasizes hands-on-science lessons in teaching a difficult subject. Includes numerous tables, illustrations and figures. Presents extensive lists of questions (memory checks) for the student to answer at the end of each chapter. The appendix contains detailed answers to these questions. The book is organized in an interesting and challenging format from the simple to the complex, and from general to specific information about essential principles of general chemistry.

US Davidson Institute for Talent Development located in Reno, Nevada offers Tips for Parents: How To Present Chemistry To Gifted Children (https://www.davidsongifted.org/search-database/entry/a10785). This web material provides parents with advice on how to introduce chemistry to gifted children. Gifted children tend to excel in the sciences and maths and can get ahead of themselves and lost in the "doing" of chemistry without getting the background information. The material is mainly focused on the periodic table because by starting them early with the basics of the table, atomic structure, electrons, bonding and the basic rules, laws and constants, we set the stage for them to launch into practical lab situations with a better understanding.

INFORMAL GIFTED STUDENTS' CHEMICAL EDUCATION ACTIVITIES

Two different sets of enrichment activities will be developed in the next phase of the project following the inquiry-based science education (IBSE) approaches where the gifted students for science will conduct research in the informal educational setting (Center KemikUm at the University of Ljubljana, Faculty of Education).

Enrichment activities for gifted students

Enrichment non-lab activities

The non-laboratory activities comprise chemistry exercises and problems where gifted students in the field of chemistry use their higher-level reasoning abilities and higher-level knowledge to complete the tasks. The compendium of exercises and problems would be a useful addition to textbooks in lower secondary school chemistry so that teachers can provide gifted students with some additional work during regular chemistry lessons.

However, such activities are not enough for gifted students to develop potentials at the specific scientific field, so in addition inquiry-based lab activities will be developed in five different areas.

Enrichment inquery-based lab activities

Hydrocolloids in Modern Gastronomy

Changing the texture of food is an important aspect of food preparation in modern gastronomy. We help ourselves with various substances, which are often borrowed from food technology. Changing the texture is done by various processes or by adding substances that change the texture of the food during processing even at low concentrations. This is especially important so that the additives do not change the taste of the prepared food. Changing the texture is important in modern gastronomy primarily to increase the eating experience. Among other methods for changing food structure, hydrocolloid gels are used for thickening food at low concentrations. But all hydrocolloids do not form gels under the same conditions. That is why in this experiment we use inquiry based learning where students have to plan a study with which they will try to find out how pH, enzymes and temperature effect the gel hardness of a certain hydrocolloid. For that matter, 5 hydrocolloids are used: agar, pectin, gelatin, carrageenan and sodium alginate.

Forensic Chemistry

Forensic chemistry uses different methods and analysis to provide leads for investigators, so they can confirm or discard their suspicions. Among the most commonly used methods are latent fingerprint detection, toxicology and electrophoresis. Different IBSE activities will be develop for gifted students to use in informal education settings.

Chemistry of Natural Compounds

The chemistry of natural compounds has been one of the most interesting fields of chemistry for many decades and has been studied by many researchers. Within the project we want to develop activities for gifted students from primary and secondary schools in the field of chemistry of natural compounds. These activities would include the development and optimization of various experimental methods for isolating compounds from plant material. Isolated compounds would be more accurately detected and possibly identified. An important part of the identified compounds would be their use in daily life (e.g. use in the pharmaceutical industry as raw material to produce important drugs, natural cosmetics, natural medicine, etc.). The experimental procedures, which would be developed in laboratories together with gifted high school students, would be optimized to such extent that they could be transferred and reproduced in school practice. It is important that this type of research in the field of chemistry of natural compounds is gradually introduced in secondary and primary schools, as this is the content that students are confronted with every day.

Green Chemistry

Green chemistry provides an exciting opportunity for gifted children to build critical and creative-thinking skills while also building skills in science, technology, engineering, and mathematics (STEM) areas. For example, the gifted students can explore issues related to sustainability and environmental concerns and thereby try to identify problems, develop research questions, gather and analyze data, develop possible solutions, and disseminate this information to others.

Green issues are especially appealing to gifted learners as they are often sensitive to the world around them and interested to engage in projects that are related with actual issues facing their communities, e.g. bioplastics, biodisel, waste reuse, etc.

Environmental Chemistry

Environmental chemistry is an important part of scientific literacy for sustainability. Activities developed according to the inquiry-based science education (IBSE) approaches will be developed in the field of ecotoxicology, water and soil pollution.

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