# Gifted students and chemical education in informal learning environment – DiSSI approach in Slovenia

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## Abstract

Students' giftedness, which is a complex, developmentally dynamic, and contextual phenomenon, is something teachers encounter every day. In the classroom, they often meet students who have exceptional potential or achieve very high learning goals. Because the gifted students are a special learning group, the chemistry teacher must introduce teaching methods and learning and teaching approaches that encourage the gifted to develop their chemical knowledge according to their potential. One such approach may be inquiry-based learning, in which students participate as active researchers, resulting in the development of scientific competencies at a level beyond the usual scope of lower and upper secondary chemistry curricula.

## Giftedness in science and/or chemistry

Pripombe dodal [SM1]: Ali ne samo "science"? V moji diplomi se spomnim, je bilo le "science", "natural science" je bilo narobe...

Pripombe dodal [SM2]: ?

Gifted students are not always able to solve complex problems in science in general. Often, a more specific talent for science is shown within the sciences such as chemistry, biology, or physics. Enrichment and acceleration programs are possible approaches for supporting gifted students, including those in the field of chemistry. The former allow gifted students to extend their learning beyond the scope of the curriculum, taking into account individual differences (e.g., research science camps, various chemistry competitions, research assignments at institutions that are not part of the school environment ...), while the latter allow acceleration of gifted students' development where it belongs, e.g., through early enrolment in school, skipping classes, etc. (Sumida and Ohashi, 2015).

Gifted students in chemistry show a high level of readiness and interest in learning new chemistry content. In learning this content, they show good concentration skills and

metacognitive maturity. They use terms related to chemistry to describe chemical concepts and phenomena, and in this sense, have an extensive natural vocabulary. Understanding of chemical concepts by gifted chemistry students is quick, rapid, in-depth, and of high quality, and does not include incomplete- or misconceptions. They are the only ones who are able to recognise these among peers during a discussion and point them out (Taber, 2010). The gifted in chemistry can easily connect new concepts with existing ones and to the natural science (chemical) phenomenon they are describing. They are able to think ahead and make mental leaps at intermediate and, for them, less important levels in building their understanding of a concept. They quickly understand the direction in which research of a chemical phenomenon should go and determine the outcomes of research in advance. The competencies of the gifted in chemistry extend to the ability to make chemical and mathematical models of a given phenomenon and to create creative and valid explanations of chemical phenomena. They are challenged by chemical problems placed in the context of real-life situations, and they connect the results of solved chemical problems to the new context without difficulty. They are capable of abstract thinking, which helps them identify patterns in data where the connections between them are not clearly visible. On this basis, they propose several alternative strategies for checking predictions or collecting data during experimental work (Gilbert and Newberry, 2007).

Gifted students like to set up hypotheses and manipulate variables in experimental research. They work persistently, perform their own activities, and create a high-quality product. Upon completion of a research paper on a particular chemical content, they are able to create an overview of the content, reflect on their thinking and learning as they seek to understand chemical concepts in depth (Benny and Blonder, 2018).

## Enriching chemistry classes for the gifted

When teaching chemistry content, it is crucial for gifted students to explore chemistry concepts in depth and over a longer period of time. Chemistry lessons should be designed using the inquiry-based teaching and learning approach that sparks interest and connects knowledge (Devetak and Ferk Savec, 2018). In this case, students are active researchers who investigate real problems and situations in the context of life situations (Devetak, 2017). It should be emphasised that inquiry-based learning is not just about solving a worksheet and writing down the results, but rather a process of building students' knowledge with the help of the teacher. The key emphases of inquiry-based learning are: (1) finding the research problem; (2) defining

research questions and hypotheses; (3) identifying dependent and non-dependent variables; (4) planning the research and testing of variables; (5) carrying out measurements and observations with which we capture data relevant to the research; (6) predicting results; (7) analysing data and obtaining results; (8) establishing conclusions; (9) reporting; and (10) evaluating (Trna, 2014).

Inquiry-based lessons must be designed with emphasis on defining research questions, based on which gifted students then analyse, synthesise, and evaluate information to find an answer. Gifted students should solve contextual chemistry problems in an interdisciplinary manner, using several different and interrelated domains. The teacher's role in this context is to encourage authentic scientific thinking and creativity. In doing so, the teacher makes sure that students take the initiative in making diverse choices about the content of the chemistry problem and in the overall planning of the work. In this way, we develop self-regulation in the gifted students - strengthening their ability to make decisions and to be self-directed in carrying out research activities. It is also an important factor for the teacher to ensure that gifted students have the opportunity to present the results of their work to an interested audience after completing the research (Devetak and Ferk Savec, 2018; Cabalsa and Abraham, 2020; Vroom Redden et al., 2020).

## DiSSI informal learning activities for the gifted

The work of the Slovenian DiSSI group (https://dissislovenia.splet.arnes.si/) focused on gifted students in the field of science especially chemistry, in the first phase of implementing DiSSI workshops in informal educational environment. The gifted acquired chemical knowledge outside of school, at the KemikUm Center (https://www.pef.uni-lj.si/raziskovanje-in-umetnost/center-kemikum/), which has been successfully operated at the University of Ljubljana, Faculty of Education (UL PEF) since 2017. The function of the KemikUm Center is based on the connection between universities, schools and companies with the aim of joint development of innovations, their use in chemistry teaching and learning, and optimization based on the evaluation of the activities carried out to contribute:

1) Transfer and successful use of development and research results in the educational process,
2) Improve the quality of teaching and learning chemistry according to the needs in school practice, local environment and in companies with activities in the field of natural sciences,
3) Promote young people's interest in chemistry and natural sciences and

**Pripombe dodal [SM3]:** Nižje se ta kratica uporablja. Predlagam, da se jo na tem mestu uvede.

4) Improve awareness of the role of chemistry and natural sciences in society and the importance of sustainable development.

The advantage of informal teaching and learning of chemistry in such an environment as, for example, the Center KemikUm UL PEF is primarily the freedom to use different teaching approaches.

Various teaching approaches and examples of good practices were developed within the project. When preparing various activities, emphasis was also placed on cooperative learning to support the learning of all four, previously mentioned groups of students. Activities developed for both lower and upper secondary school students include the following developed DiSSI learning modules:

1) “Forensics Science”
2) “Environmental Chemistry – hydrosphere pollution”
3) “Green Chemistry of the Future”
4) “Medical Active Substances in Pepper”

All learning modules are based on the principle of inquiry-based learning, which has proven as effective in teaching and learning chemistry for gifted students, as well as for others, but with certain adaptations to the learning approach.

At the faculty, we have conducted fifteen experimental workshops based on the above modules so far. The workshops have been attended by 310 lower and upper secondary students (aged 13 to 16) from schools all over Slovenia.

## “Forensic sciences” module

With more than 160 participants, the "Forensic Science" module proved to be the most popular among lower secondary school students and teachers. Participants were presented with a fictional crime scenario with a description of the victim and suspects. Their task was to analyse the collected evidence by conducting various experiments combined with an inquiry-based learning approach and find out who among the suspects committed the crime. The workshop lasted an average of 4 school hours (45 minutes each) and consisted of four workstations

**Pripombe dodal [SM4]:** Je to OK, da enkrat piše Science z veliko, drugič z malo. To je pri več besedah v članku nepoenoteno.

covering different fields of forensic science, such as fingerprint analysis, unknown substance analysis, fibre analysis, and DNA analysis (Figure 1).


**Figure 1. Evidence analysis.**

**Pripombe dodal [SM5]:** Bi se tu, ker je slika sestavljena iz 4 segmentov, dodalo še podrobnejši opis slike?
Npr.
"From left to right: … "

At each workstation, students were provided with a worksheet. Each worksheet gave them a forensic problem to solve (see supplemental online material). They began by defining research questions and hypotheses, proceeded to design and conduct experiments, and concluded by discussing the results obtained and drawing appropriate conclusions. The module proved to be of equal interest to gifted and non-gifted students, with the gifted showing a more positive attitude toward inquiry-based learning.

The first few iterations of the workshop were evaluated and provided us with results, based on which some adaptations were made. We found that most students had difficulty in properly developing the research design and conducting experiments related to the workstation for analysis of unknown substances. We therefore used a learning approach from our project partners in Germany, who used tip cards with pictures for students with lower language skills to help them perform experiments. This adaptation had a positive impact on the way students conducted experiments. Another adaptation was the inclusion of game-based learning in our module. The game-based approach to chemistry learning was adopted from our North Macedonian partners. We used a simple puzzle that, when put together correctly under UV light, revealed the name of the suspect who had committed the crime. Students received a piece of the puzzle at each workshop based on the results of the evidence analysis (Figure 2). The

adaptations had a positive effect on the non-gifted students' interest in learning forensic science, but not so much on the gifted students, who were more interested in the non-adapted module.

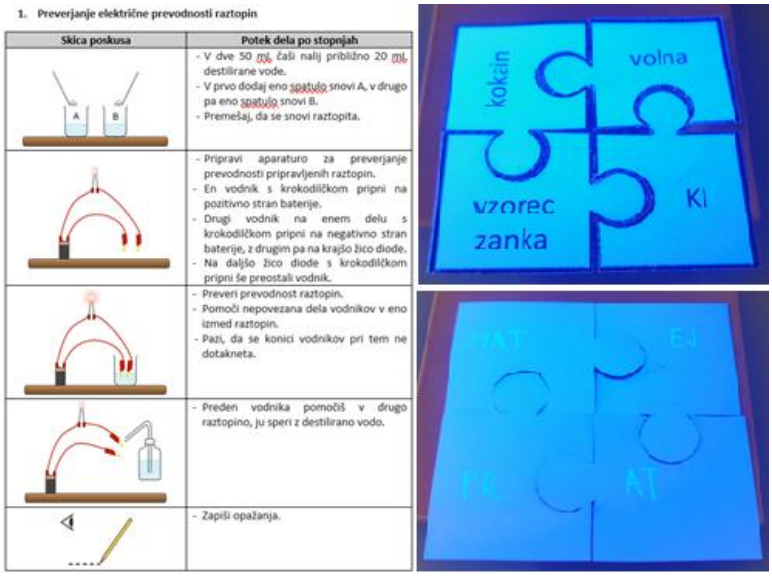


**Figure 1. Module adaptations – experiments instructions for students who have difficulties reading (left) and developing the experimental design in the specific part of the inquiry-based teaching approach (right).**

Pripombe dodal [SM6]: Glede na to, da sta dve sliki se mi zdi smiselno, da se doda še "levo/desno".

As part of the DiSSI project, Webinars were organised and conducted webinars for in-service teachers of science, particularly chemistry, in which they learned about the theoretical basis of teaching and learning chemistry through inquiry, as well as aspects and adaptations of teaching chemistry to more effectively target gifted students in science, particularly chemistry. A total of 85 in-service teachers participated in the workshops. Participants also developed their own designs for DiSSI learning modules, which they later presented to their colleagues.

The DiSSI philosophy for teaching and learning chemistry was also presented to in-service science teachers who teach science, chemistry, and biology to students ages 12 to 17, and to elementary teachers who teach science to students ages 6 to 11. A total of 82 pre-service teachers participated in the workshops. They all conducted experiments focused on inquiry-based science education and developed ideas and prepared designs for their own draft DiSSI modules.

## Conclusion

In Slovenia, a total of 82 pre-service and in-service teachers and 310 of their students participated in the ERASMUS+ DiSSI project. The main conclusion is that teaching and learning of chemistry content beyond the usual learning standards of the national chemistry curricula for lower and upper secondary schools can be applied in the informal learning environment at the university. Such an environment encourages students to learn additional chemistry concepts, such as forensic science concepts, which stimulate interest in inquiry-based chemistry learning approaches. Such approaches are also relevant for developing students' research competence according to teachers who participated in the DiSSI workshops. It can be summarised at the end, that DiSSI project was a success in Slovenia.

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## Authors' biography

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