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# Inquiry-Based Chemistry Education Activities in a Non-formal Educational Setting for Gifted Students

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Student giftedness is a complex, developmentally dynamic and contextual phenomenon that teachers confront every day. In the classroom, teachers often meet students who have exceptional potential or achieve very high learning goals. The aim of this study is to illustrate the evaluation of inquiry-based learning activities in a specific context (Diversity in Science towards Social Inclusion learning modules) implemented in a non-formal educational setting for gifted students in relation to their level of individual interest and their autonomous and controlled motivation, comparing different groups of students. We investigate how these activities affect the students' attitudes towards inquiry-based learning, their situational interest and their interest in science careers. A total of 264 Slovenian lower secondary school students participated in the study. The students participated in non-adapted and adapted activities based on the inquiry-based learning approach. The data were collected using pre- and post-activity questionnaires. Participation in the study, which took place in the period between the 2021/22 and the 2022/23 school years, was voluntary. The data was collected anonymously and used for research purposes only. The results show several statistically significant differences in how students' level of individual interest, autonomous motivation and controlled motivation for learning chemistry affects their attitudes towards inquiry-based learning, their situational interest in Diversity in Science towards Social Inclusion activities and their interest in science careers. For the gifted and non-gifted students who participated in "Forensics Science" lab activities before and after the adaptations to the modules, the results related to their attitudes towards inquiry-based learning and situational interest are also reported. Thus, the results of the study provide useful insights for researchers in the field of chemistry education as well as for chemistry teachers in lower and

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upper secondary schools. The presented study is a good example of best practices that chemistry teachers can apply in teaching chemistry, thus enabling all students, not only the gifted ones, to learn chemistry using the inquiry-based learning approach.

**Keywords:** non-formal education, gifted students, inquiry-based learning, interest, motivation

# Učenje z raziskovanjem na področju kemije za nadarjene učence v neformalnem izobraževalnem okolju

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Nadarjenost učencev je kompleksen, razvojno dinamičen in kontekstualen pojav, s katerim se učitelji vsakodnevno spoprijemajo. V razredu se pogosto srečujejo z učenci, ki imajo izjemni učni potencial ali dosegajo zelo visoke učne standarde. Namen te raziskave je prikazati rezultate aktivnosti učenja z raziskovanjem v specifičnem kontekstu učnih modulov, razvitih v sklopu projekta DiSSI (Diversity in Science towards Social Inclusion) in izvedenih v sklopu neformalnega izobraževanja za nadarjene učence v povezavi z njihovo stopnjo individualnega interesa ter avtonomno in kontrolirano motivacijo, pri čemer primerjamo različne skupine učencev. Preučevano je bilo, kako izvedene laboratorijske aktivnosti učnih modulov vplivajo na odnos učencev do učenja z raziskovanjem, njihov situacijski interes in zanimanje za naravoslovne poklice. V raziskavo je bilo vključenih 264 slovenskih učencev, ki so sodelovali v izvedbi neprilagojenih in prilagojenih učnih modulov v kontekstu učenja z raziskovanjem. Podatki so bili zbrani z vprašalnikom pred izvedeno laboratorijsko aktivnostjo in po njej. Sodelovanje v raziskavi, ki je potekala med šolskimi leti 2021/22 in 2022/23, je bilo prostovoljno. Zbrani podatki so anonimni, uporabljeni pa so bili le v raziskovalne namene. Rezultati kažejo več statistično pomembnih razlik v tem, kako stopnja individualnega interesa, avtonomna in kontrolirana motivacija učencev za učenje kemije vplivajo na njihov odnos do učenja z raziskovanjem, situacijski interes po izvedbi aktivnosti učnih modulov in zanimanje za naravoslovne poklice. V prispevku so predstavljeni tudi rezultati glede odnosa učencev, nadarjenih in nenadarjenih, ki so sodelovali v aktivnostih učnega modula »Naravoslovje v forenzični znanosti« pred prilagoditvami učnih modulov in po njih. Rezultati raziskave ponujajo koristne vpoglede za raziskovalce na področju kemijskega izobraževanja pa tudi za učitelje kemije v osnovnih in srednjih šolah. Predstavljena raziskava je primer dobre prakse, ki ga lahko učitelji kemije uporabijo pri poučevanju kemije, s čimer omogočijo vsem učencem, ne le nadarjenim, učenje kemije z uporabo pristopa učenja z raziskovanjem.

**Ključne besede:** neformalno izobraževanje, nadarjeni učenci, učenje z raziskovanjem, interes, motivacija

## Introduction

Diversity in Science towards Social Inclusion (DiSSI) – Non-formal Education in Science for Students' Diversity is an international Erasmus+ project with partners from Germany, Ireland, the United Kingdom, Northern Macedonia and Slovenia.

The aim of the project was to develop educational strategies in chemistry in a non-formal learning environment for diverse students to simultaneously address four dimensions of student diversity: (1) those who come from a lower socioeconomic status background, (2) those who belong to an ethnic or cultural background that differs from the majority in society, (3) those with lower language skills for effective communication in the predominant language in society, and (4) those who are considered gifted in science or chemistry.

As part of the project, the Slovenian team focused on activities for gifted students. Identification of giftedness is a challenging task that requires the collaboration of teachers, school counsellors, parents and external experts. In Slovenia, this process is guided by the instructions proposed by the working group for the preparation of the concept "discovering and working with gifted students in the nine-year primary school". According to this concept, the first step in identifying giftedness is to define students who may be gifted based on criteria that do not include tests or assessment instruments. The second step is a more in-depth and detailed analysis to which methodologically sound instruments can be applied. In the third and final step of identification, parents are informed about their children's giftedness and have an opportunity to give their opinion about it (Žagar et al., 1999). Gifted students should be given an opportunity to develop their potential in the best possible way in the field of science as well, especially in chemistry. If they show an interest in acquiring chemistry knowledge at a higher level than specified in the national curriculum for chemistry, they should have an opportunity to participate in enrichment activities. Such activities may include inquiry-based learning (IBL) in a specific context.

IBL as a learning method applied in the specific domain of science teaching and learning can be defined as Inquiry-Based Science Education (IBSE) (Dunne et al., 2013). For the purpose of the present paper, IBL is applied in a non-formal educational setting in the KemikUm Centre at the Faculty of Education of the University of Ljubljana. After participating in science-related non-formal activities, students often show better performance, greater confidence in their ability to solve science tasks and more enjoyment in learning science (OECD, 2012).

The purpose of the study presented in this paper is to evaluate the effectiveness of DiSSI learning modules based on IBL in the context of gifted students in a non-formal learning setting and to investigate students' attitudes towards this method of chemistry learning. Students' interest and motivation in chemistry learning and their IBL experiences in school were assessed as well as the impact of these variables on the success of DiSSI module implementation.

### Students' giftedness for academic achievements in general and in science

Students whose performance in certain areas is higher than that of their peers are referred to as gifted students and show high potential and achievement at all levels of education (Worrel et al., 2019; State Notes: Gifted and Talented, 2006). Their characteristics are curiosity, persistent pursuit of interests and questions, awareness of the environment, recognition of the relationship between seemingly desperate ideas, generation of ideas, etc. (Tuttle et al., 1988). Hornstra et al. (2020) reported differences in motivation levels between gifted and non-gifted students, although these differences were only minor. Phillips and Lindsay (2006) found that both types of motivation (extrinsic and intrinsic) are present in gifted students, while Topcu and Leana-Tascilar (2018) found that both types can predict academic achievement of gifted students. In order to increase gifted students' interest and motivation, they need to be given tasks that they find challenging and to participate in high-ability groups (Hornstra et al., 2020; Little, 2012; Phillips & Lindsay, 2006). Little (2012) stated that, in order to be challenging for gifted students, the topic must be meaningful and contain elements of enjoyment. When this is not the case, students do not have an opportunity to pursue their personal interests. The pace and level of teaching and learning can provide an appropriate level of challenge for gifted students and increase their motivation. With a positive attitude towards inquiry activities in science classrooms, students' interest in science learning also increases (Eltanahy & Forawi, 2019). Levinson (2007) and Kind (2007) suggested that controversial socio-scientific issues and context-based science in general can be an effective vehicle for stimulating gifted students in science learning.

Following these guidelines from the literature, DiSSI modules with interesting problems from everyday contexts were developed in order to stimulate gifted students' interest in learning new chemistry concepts.

## Students' individual and situational interest in learning chemistry

Interest is defined as a psychological state involving a high level of attention, effort and commitment to an activity (Chen & Darst 2002). The authors define two types of interest: individual and situational. Individual interest is a consequence of the individual's psychological state and is related to preferences for activities. It allows individuals to persist in a situation despite frustrations and feelings of failure. Students with higher levels of individual interest tend to be more focused and relaxed, remember content better, strive to do well in written knowledge tests (Renninger, 2000) and have a better capacity for knowledge acquisition (Rotgans & Schmid, 2017). Individual interest therefore enhances student learning. Cheung (2018) found that scientific self-concept is the most important factor for students' individual interest. Self-concept is higher in gifted students than in non-gifted students (Košir et al. 2016; Metin & Kangal, 2012). Academic self-concept is influenced by the educational setting. When students learn in a high ability setting, they have a lower self-concept; therefore, high ability students have a higher academic self-concept in a non-high ability setting such as schools (Tokmak et al. 2021).

Situational interest depends on external stimuli and internal dispositions, and can be influenced by individual interest (Rotgans & Schmid, 2018). It arises due to environmental factors, such as a task instruction or an engaging text (Schraw et al., 2001). In research by Linnenbrick-Garcia et al. (2010) and Chen and Darst (2002), situational interest was shown to be unrelated to individual interest. Situational interest depends on situational factors, such as collative factors, which can deepen interest in an individual task (Durik & Harackiewicz, 2007). Active involvement combined with novelty play a key role in fostering students' situational interest (Snětinová et al., 2018). Knogler et al. (2015) found that specific situation effects have a strong influence on self-reported situational interest, while research by Liu et al. (2022) showed that IBL can significantly improve students' level of situational interest, although it does not have a significant influence on students' individual interest.

According to the literature, it is reasonable to assume that, when trying to implement a new educational strategy such as DiSSI modules, both types of interest can be measured, considering situational interest and individual interest as independent variables.

## Autonomous and controlled motivation for learning chemistry

Motivation is the ability and will to learn and strive with purpose. It refers to the choices people make about what goals to strive for and the amount of effort they put forth to achieve those goals (Crookes & Schmidt, 1991). Student learning is driven by two sources: external and internal. In general, there are two types of motivation: extrinsic and intrinsic (Filgona et al. 2020). Ryan and Deci (2000) defined the motivation continuum as ranging from amotivation to motivation, with amotivation being a state in which people lack motivation. According to Self-Determination Theory (SDT), people are likely to be unmotivated when they lack either a sense of efficacy or a sense of control over the desired outcome. Extrinsic motivation, along with intrinsic factors and identified and integrated regulation, is classified as autonomous motivation (Feri et al., 2016) or intrinsic motivation (Ratelle et al., 2007). This type of motivation can be undermined by external factors such as monetary rewards (Ryan & Deci, 2000) and can help individuals to be more determined in their future career choices (Paixao et al., 2021). Controlled motivation includes external and introjected regulation with an external locus of causality (Gegenfurtner et al., 2009). Controlled motivation can be understood as extrinsic motivation (Ratelle et al., 2007) in which people's behaviour is controlled by external conditions (Ryan & Deci, 2000).

Motivation can be increased by higher levels of autonomy given to students by teachers (Ushida, 2011, Hinnersmann et al., 2020). Emphasising student autonomy decreases students' conscious learning and therefore motivates them (Bravo et al., 2017). In a study by Hornstra et al. (2020), teachers were found to provide gifted students with less structured tasks and give them more autonomy. However, no statistically significant differences were found between gifted and non-gifted students in terms of their motivation levels. Research by Al-Dhamit and Kreishan (2013) showed that gifted students have high extrinsic and intrinsic motivation, but not significantly higher than non-gifted students. Bosco et al. (2019) found that student-centred learning, in which students experience hands-on activities, increases students' autonomous motivation, but controlled motivation can also be increased through a more competitive learning environment (Cropper, 1998).

Given these aspects of motivation that influence learning, the DiSSI modules were designed to be student-centred and to allow students to be more autonomous in inquiry-based laboratory work.

## Inquiry-based learning

IBL is a student-centred learning method (Reid & Ali, 2020) "in which learning is driven by a process of inquiry" (Khan & O'Rourke, 2004, p. 1). In this process, students seek an answer to a research question or attempt to solve problems by conducting experiments, following the stages of scientific inquiry that scientists use to collect and analyse data and draw conclusions. In the context of chemistry education, these activities lead students to acquire new knowledge and skills (Pedaste et al., 2015). The IBL method is based on a constructivist approach to learning, which assumes that learners create their own understanding through active participation in the learning process (Driver & Oldham, 1986). It is a type of learning that includes hands-on activities to motivate and engage students (Suduc et al., 2015). It is also a form of active learning in which students interact with each other and pave the way for interaction with the teacher (Aulia et al., 2018). It has been found that students who experience hands-on activities find the learning content more enjoyable and relevant (Suduc et al., 2015). Inquiry-based learning also improves student learning outcomes (Wang et al., 2015; Tawfik et al., 2020; Anjani et al., 2018).

Eltanahy and Forawi (2019) found that students have positive attitudes towards inquiry-based activities in science classrooms and therefore show more interest in learning about science, although this needs to be guided to some extent by the teacher (Szalaya, et al., 2021). It is therefore reasonable to assume that individual interest in chemistry learning may influence how students perceive learning and how IBL activities influence students' situational interest and their attitudes towards the IBL approach and activities conducted in the chemistry laboratory. However, some studies (Snětinová et al., 2018; Szalaya et al., 2021) have concluded that IBL does not have a statistically significant impact on students' interest and knowledge levels. When students' interest is aroused, relationships between students are also enriched, resulting in an improvement in their attitudes towards science (Aktamiş & HİĞde, 2016).

Some research (West, 2007; Özgür & Yilmaz, 2017; Trna, 2014) conducted with gifted students has concluded that IBL can increase gifted students' motivation to learn. This type of learning can also be effective for gifted students (Özgür & Yilmaz, 2017; Eysink et al., 2015; Can & Inel Ekici, 2021; Juriševič & Devetak, 2018), as its components meet their educational needs (Trna, 2014).

### Aim and research questions

The aim of the study presented in this paper was to investigate how (1) individual interest in learning chemistry and (2) autonomous and controlled motivation for learning chemistry among different groups of students affect their attitudes towards IBL, their situational interest and their interest in science careers. Non-formal and informal activities are positively related to science learning, which is why DiSSI modules were developed for implementation in a non-formal learning environment.

The research questions guiding this study are as follows:

1. Are there any significant differences in students' attitudes towards IBL, their situational interest, and their interest in science careers based on their individual interest in chemistry learning and their autonomous and controlled motivation for chemistry learning?
2. Are there any significant differences in students' attitude towards IBL and their situational interest based on DiSSI "Forensic Science" module adaptations?
3. Are there any significant differences in students' attitudes towards IBL, situational interest, individual interest, autonomous motivation and controlled motivation based on their general academic giftedness, self-reported giftedness for chemistry and previous experience with IBL in school?

## Method

The non-experimental and pre-post educational research approach was used in this study.

### Participants

A total of 264 students attending grades 7, 8 and 9 at 17 lower secondary schools across Slovenia participated in this study. The participants were between 13 and 15 years old, so informed consent to participate in the study was obtained from their parents and caregivers. Of the 264 participants, 164 were girls, 96 were boys and 4 students chose the option "other" regarding their gender. A total of 112 of the students were identified as gifted, with an average grade in chemistry of 4.8 ($SD$ = 0.60) out of a maximum of 5, while 152 were not identified as gifted and had an average grade in chemistry of 4.1 (*SD* = 0.88) out of a maximum of 5. The students are officially classified as generally gifted at school according to the concept "discovering and working with gifted students in the nine-year primary school" presented above. When the students were asked whether they think they are gifted for chemistry, 118 said yes and 146 said no. However, this is an unofficial classification. Of the 264 students, 136 participated in the DiSSI module "Forensic Science", which proved to be our most popular module and was adapted with the teaching strategies used by our project partners. Out of these 136 students, 68 participated in the non-adapted module and 68 in the adapted module.

### Instruments

#### *Pre-DiSSI activity questionnaire*

The anonymous questionnaire given to the lower secondary school students participating in the study before they performed the laboratory activity consisted of three parts.

In the first introductory section, the students were informed that the purpose of the questionnaire was to find out their opinion about learning chemistry before participating in the laboratory activity. In the subsequent section of the first part of the questionnaire, the students provided information on demographics, such as their age, gender and grade level, whether they are identified as gifted, whether they consider themselves as gifted in chemistry, their final grade in chemistry from the previous school year, and the their prediction for their final grade in chemistry in the current school year.

In the second section, the students expressed their agreement with 18 different items related to the following three dimensions: individual interest (5 items), interest in a science career (7 items) and self-concept (6 items). In the third section, the students determined whether they agree with items on two motivational dimensions: autonomous motivation (5 items) and controlled motivation (5 items). Each item in this instrument was rated on a five-point Likert scale with the following scoring options: strongly disagree = 1, disagree = 2, unsure = 3, agree = 4, strongly agree = 5.

#### *Post-DiSSI activity questionnaire*

The anonymous questionnaire given to the lower secondary school students after the laboratory activity contained the same introductory and demographic data collection section as the pre-questionnaire.

In the second part of the questionnaire, the students had to evaluate their agreement with items related to their situational interest for DiSSI activities in a non-formal educational environment (10 items). Each item in the second part was rated on a five-point Likert scale with the following scoring options: strongly disagree = 1, disagree = 2, unsure = 3, agree = 4, strongly agree = 5. There was also a question asking the students to write down three things of their choice that they found most interesting about this chemistry activity.

In the third part of the questionnaire, the students evaluated the implementation of IBL in the chemistry classroom at their school (five items).

In the fourth part of the questionnaire, the students had to express their agreement with items that related to their attitude towards IBL implemented during the DiSSI activity (7 items). Each item in the fourth part was rated on a four-point scale with the following scoring options: strongly disagree = 1, disagree = 2, agree = 3, strongly agree = 4.

***Research design***

The research was conducted from September 2021 to May 2023. All of the instruments were applied anonymously. Activities developed for both lower and upper secondary school students include the following DiSSI learning modules: (1) "Forensics Science", (2) "Environmental Chemistry – Hydrosphere Pollution", (3) "Green Chemistry of the Future", (4) "Biologically Active Substances in Pepper", and (5) "Chemistry of Honey". All of the learning modules are based on the principle of IBL, which has proven to be effective in teaching and learning chemistry for gifted students as well as for others, but with certain adaptations to the learning approach. The main learning goals of the DiSSI modules are to give students an opportunity to solve specific scientific problems by applying the IBL approach in a non-formal educational setting and to stimulate the development of their scientific competences and interest in real-life chemistry.

In the "Forensics Science" DiSSI module, the participants are presented with a fictional crime scenario with a description of the victim and suspects. Their task is to analyse the collected evidence by conducting various experiments (latent fingerprint detection, toxicology and DNA electrophoresis) in order to find out which of the suspects had committed the crime.

The DiSSI module "Environmental Chemistry – Hydrosphere Pollution" is an important part of scientific literacy for sustainability of lower and higher secondary school students. Within this module, students must conduct a series of experiments from the field of ecotoxicology and water and soil pollution using analytical chemistry methods, such as spectroscopy.

The "Green Chemistry of the Future" DiSSI module offers gifted students an exciting opportunity to develop critical and creative thinking while gaining STEM skills. Through this module, gifted students explore topics related to sustainability and environmental concerns in order to identify problems, develop research questions, collect and analyse data, develop possible solutions, and share this information with others. "Green issues" are especially appealing to gifted students, as such students are often sensitive to the world around them and are interested in projects related to current issues in their communities, e.g., biodiesel production, waste reuse, etc.

The DiSSI module "Biologically Active Substances in Pepper" is related to the chemistry topic of natural compounds and includes many activities for gifted students, especially those in higher secondary schools. Experimental activities include the development and optimisation of various experimental methods for isolating compounds from plant material. The isolated compounds are then detected and possibly identified. An important part of the identified compounds is their use in industry (e.g., use in the pharmaceutical industry as raw material to produce important drugs, natural cosmetics, etc.).

In the "Chemistry of Honey" DiSSI module, gifted students use the IBL approach to explore a variety of experiments to determine the physical and chemical properties of different types of honey. They investigate the colour, smell and taste of honey, as well as its viscosity. They also investigate the electrical conductivity of aqueous solutions containing different types of honey and conduct tests to determine the presence of reducing sugars. After completing these experiments, they evaluate these properties on unidentified samples to determine the origin and composition of the honey. All of the DiSSI modules are available in national languages on the official website of the DiSSI project: https://dissi.org/materials-for-sharing/.

Special DiSSI boxes were prepared for each DiSSI learning module, which contained all of the necessary tools, materials, instructions, etc. to enable the practical implementation of the DiSSI learning modules outside the University of Ljubljana's KemikUm laboratory. These boxes can be viewed at the official Slovenian website of the DiSSI project: https://dissislovenia.splet.arnes.si/izobrazevanje-uciteljev/.

Before the laboratory activities (DiSSI module application), the students had to fill in a pre-lab questionnaire, and after the lab work, they had to fill in a post-lab questionnaire. Both questionnaires were completed by the students in both of the groups participating in the non-adapted and adapted DiSSI module application.

The DiSSI project ran in four phases. In the first phase, several DiSSI modules were developed. In the second phase, the DiSSI modules were used in lab work or a workshop for lower secondary school students in a non-formal educational setting at the University of Ljubljana's KemikUm laboratory. Each workshop lasted an average of four school hours (45 minutes each).

In the third phase of the project, the module "Forensics Science" was adapted to the teaching strategies used by our project partners. The module was adapted to the needs of other possible student diversities, such as lower language skills and belonging to an ethnic or cultural environment that is different from the majority of society, but not to students with a lower socioeconomic status. In order to meet these requirements, the adaptations included more structured and guided instructions for IBL and playful activities such as puzzles.

The data collected with the questionnaires were transferred to Excel and SPSS 22. Descriptive (frequency tables) and inferential statistics (one-way ANOVA and t-test) were used to process the data. The values for the groups of students that were tied to individual interest and autonomous motivation were calculated based on the level of agreement with the questions about individual interest or autonomous motivation. According to the number of points obtained in each category, the students were divided into three groups (Table 1).

**Table 1**

*Criteria for dividing the students into three groups*

| Number of points | Group of students |
|---|---|
| $< M - SD$ | Low level of individual interest/autonomous motivation |
| $< M \pm SD >$ | Average level of individual interest/autonomous motivation |
| $> M + SD$ | High level of individual interest/autonomous motivation |

## Results and discussion

The results are presented based on the research questions stated above. One-way ANOVA was used to examine how the students' individual interest affects their attitudes towards IBL, situational interest and interest in science careers.

The students were divided into three groups based on their individual interest for chemistry learning (Group 1: low interest, Group 2: average interest, Group 3: high interest). The difference in the students' attitudes towards IBL between the three groups is statistically significant ($F(2, 258) = 26.084$; $p < .001$). Post hoc comparisons using Tukey HSD showed that there is a statistically significant difference ($p < .001$) between the mean scores for Group 1 ($M = 19.02$; $SD = 3.00$) and Group 3 ($M = 23.03$; $SD = 2.48$), between Group 2 ($M = 20.81$; $SD = 2.83$) and Group 3 ($p < .05$), and also between Group 1 and Group 2 ($p < .05$).

A significant difference was also found when comparing situational interest between the three groups with a different level of individual interest for learning chemistry ($F(2, 254) = 24.344$; $p < .001$). The test of homogeneity of variances was statistically significant ($F(2, 258) = 3.923$; $p < 0.05$), so the Welch test of equality of means was applied. The Tukey HSD post hoc test showed a statistically significant difference ($p < .05$) between the mean scores for Group 1 ($M = 33.68$; $SD = 6.16$) and Group 3 ($M = 41.54$; $SD = 4.08$), between Group 2 ($M = 37.92$; $SD = 5.72$) and Group 3 ($p < .05$), and also between Group 1 and Group 2 ($p < .05$). These results contrast with previous findings by Linnenbrick-Garcia et al. (2010) and Chen and Darst (2002), who showed that situational interest was unrelated to individual interest. However, the results in the present study are consistent with Rotgans and Schmid (2018), who concluded that situational interest depends on external stimuli but can also be influenced by individual interest. It is difficult to explain mutually exclusive results from different authors, but it may be related to students' self-concept, which is one of the most important predictors of students' individual interest (Cheung, 2018) and is influenced by the educational setting, as noted by Tokmak et al. (2021). Schraw et al. (2001) found that task setting is also a predictor of situational interest, and it is possible that the IBL learning setting is the cause of the higher scores in both variables, which are uncorrelated.

When comparing the students' interest in science careers, a significant difference was found between the three groups regarding individual interest for learning chemistry ($F(2, 256) = 44.489$; $p < .001$). The Tukey HSD post hoc test showed a statistically significant difference ($p \leq .001$) between the mean scores for Group 1 ($M = 17.54$; $SD = 5.12$) and Group 3 ($M = 26.21$; $SD = 3.79$), between Group 2 ($M = 21.13$; $SD = 4.81$) and Group 3, and also between Group 1 and Group 2. These results confirm the connection between the level of individual interest and the preference for an activity already shown by Chen and Darst (2002). Students who show higher levels of individual interest have more positive attitudes towards the IBL learning activity and also show a higher level of interest in a future science career. The interest in a science career could also be explained by Aktamiş and Hİğde's (2016) study, which found that students with higher levels of interest have a better attitude towards science and therefore enjoy science more, which also affects their attitude towards IBL.

In order to explore how students' autonomous motivation for learning chemistry affects their attitude towards IBL, their situational interest and their interest in science careers, one-way ANOVA was used. The students were divided into three groups based on their autonomous motivation for learning chemistry (Group 1: low autonomous motivation, Group 2: average autonomous motivation, Group 3: high autonomous motivation).

The difference in the students' attitude towards IBL between the three groups is statistically significant ($F(2, 259) = 21.805$; $p < .001$). Post hoc comparisons using Tukey HSD showed that there is a statistically significant difference ($p < .05$) between the mean scores for Group 1 ($M = 19.00$; $SD = 3.10$) and Group 3 ($M = 23.18$; $SD = 2.09$), between Group 2 ($M = 21.02$; $SD = 2.90$) and Group 3 ($p < .05$), and also between Group 1 and Group 2 ($p < .05$). The DiSSI modules included IBL learning activities that involve hands-on activities, as stated by Suduc et al. (2015). Bosco et al. (2019) previously found that educational settings in which students experience hands-on activities can increase their autonomous motivation. The results can also be explained by the autonomy given to the students to complete the activities in the DiSSI modules. By giving students more autonomy, their autonomous motivation can be increased (Ushida, 2011; Hinnersmann et al., 2020) as conscious learning is reduced (Bravo et al., 2017).

A significant difference was also found when comparing situational interest between the three groups of students with different levels of autonomous motivation ($F(2, 255) = 14.557$; $p < .001$). The test of homogeneity of variances was statistically significant ($F(2, 255) = 4.993$; $p < 0.05$), so the Welch test of equality of means was applied. The Tukey HSD post hoc test showed a statistically significant difference ($p < .05$) between the mean scores for Group 1 ($M = 34.73$; $SD = 3.11$) and Group 3 ($M = 41.66$; $SD = 3.56$), between Group 2 ($M = 38.03$; $SD = 5.80$) and Group 3 ($p < .05$), and also between Group 1 and Group 2 ($p < .05$). Autonomous motivation is composed of intrinsic motivation, identified and integrated regulation, and extrinsic motivation (Feri et al., 2016), so it seems possible that the level of situational interest, which is influenced by situational factors, as noted by Schraw et al. (2001), may be influenced by autonomous motivation. Schraw et al. (2001) also noted that teachers who want to increase students' situational interest need to focus on enhancing students' autonomy.

When comparing students' interest in science careers, it was found that there was a significant difference between the three groups of students with different levels of autonomous motivation ($F(2, 257) = 35.513$; $p < .001$). The Tukey HSD post hoc test showed a statistically significant difference ($p < .05$) between the mean scores for Group 1 ($M = 17.44$; $SD = 5.22$) and Group 3 ($M = 26.46$; $SD = 4.63$), between Group 2 ($M = 21.53$; $SD = 4.73$) and Group 3, and also between Group 1 and Group 2. These results can be explained by the relatively good relationship between autonomous motivation and individual determination regarding future career, as highlighted by Paixao et al. (2021).

In order to explore how controlled motivation for learning chemistry affects students' attitudes towards IBL, their situational interest and their interest in science careers, one-way ANOVA was used. The students were divided into three groups based on their controlled motivation for learning chemistry (Group 1: low controlled motivation, Group 2: average controlled motivation, Group 3: high controlled motivation). There was no significant difference when comparing the students' attitudes towards IBL ($F(2, 260) = 2.071$; $p = .128$). The characteristics of the IBL learning method noted by Suduc et al. (2015) and the National Science Education Standards (1996) are not as connected to controlled motivation as they are to autonomous motivation, as the above results confirm.

There was no significant difference comparing situational interest between the three groups of students regarding their controlled motivation for learning chemistry ($F(2, 256) = .545$ $p = .580$). These findings do not support the findings of previous authors such as Rotgans and Schmid (2018) and Schraw et al. (2001), who found that situational interest is influenced by external factors. One possible explanation for the present results could be that situational interest is enhanced by giving students more control and autonomy, factors that are connected to autonomous rather than controlled motivation.

When comparing the students' interest in science careers, it was found that there was a significant difference between the three groups of students with different levels of controlled motivation for learning chemistry ($F(2, 258) = 4.710$; $p = .01$). The Tukey HSD post hoc test showed a significant difference ($p < .05$) between the mean scores for Group 1 ($M = 18.97$; $SD = 6.54$) and Group 3 ($M = 22.68$; $SD = 4.70$), and also between Group 1 and Group 2 ($M = 21.83$; $SD = 5.23$). There was no significant difference between the mean scores for Group 2 and Group 3. As noted by Gegenfurtner (2009), controlled motivation includes external regulations. One possible explanation for these results is that scientific careers are often perceived as prestigious by society, and therefore parents and the media influence students' perceptions of these careers as external factors.

**Table 2**

*Summary of results regarding the first research question*

| | | Dependent variables | | |
|---|---|---|---|---|
| | | Attitude towards IBL | Situational interest | Interest in science careers |
| Independent variables | Individual interest | $F(2, 258) = 26.084$; **$p < .001$** | $F(2, 254) = 24.344$; **$p < .001$** | $F(2, 256) = 44.489$; **$p < .001$** |
| | Autonomous motivation | $F(2, 259) = 21.805$; **$p < .001$** | $F(2, 255) = 14.557$; **$p < .001$** | $F(2, 257) = 35.513$; **$p < .001$** |
| | Controlled motivation | $F(2, 260) = 2.071$; $p = .128$ | $F(2, 256) = .545$ $p = .580$ | $F(2, 258) = 4.710$; **$p = .01$** |

As shown in Table 2, it can be concluded that both individual interest and autonomous motivation affect students' attitudes towards IBL, their situational interest and their interest in science careers, whereas controlled motivation only affects students' interest in science careers.

The t-test was used to examine how the "Forensic Science" module adaptations affected the students' attitudes towards IBL and their situational interest. However, no significant differences were found between the students who attended our "Forensics Science" workshop before and after the adaptations with regard to their attitude towards IBL ($t$ = -.437, $df$ = 134, $p$ = .663) and their situational interest ($t$ = -.696, $df$ = 131, $p$ = .488). The DiSSI activities were more structured due to the adaptions. Although the results show no differences between the groups, by observing the students' work in the laboratory it could be concluded that the adaptations helped the students to conduct experiments.

The t-test was used to examine how the students' general academic giftedness, self-reported giftedness for chemistry, and previous experience with IBL in school affected their attitudes towards IBL, situational interest, individual interest, and autonomous and controlled motivation.

When comparing the gifted and non-gifted students, a significant difference was found between the groups in their autonomous motivation ($t$ = 3.514, $df$ = 260, $p$ = .019), with the gifted students achieving a higher mean score ($M$ = 19.56, $SD$ = 2.98) than the non-gifted students ($M$ = 18.41, $SD$ = 3.50). On the other hand, no significant differences were found between the gifted and non-gifted students in their controlled motivation ($t$ = 4.599, $df$ = 246.6, $p$ = .542). These results support the idea of Hornstra et al. (2020), who found that teachers give gifted students less-structured tasks that allow them more autonomy, which is an important factor for autonomous motivation. However, previous authors, such as Al-Dhamit and Kreishan (2013), found no significant differences between gifted and non-gifted students in terms of their autonomous and controlled motivation. Hornstra et al. (2020) also found no significant differences in motivation levels between gifted and non-gifted students.

Students who think they are gifted for chemistry ($M$ = 20.18, $SD$ = 2.80) also showed a significantly higher level of autonomous motivation ($t$ = 5.196, $df$ = 260, $p$ < .001) compared to students who think they are not gifted ($M$ = 18.15, $SD$ = 2.80). When comparing controlled motivation between the two groups, there were no significant differences ($t$ = -.682, $df$ = 261, $p$ = .496).

A significant difference was also found in the students' individual interest for learning chemistry ($t$ = 4.599, $df$ = 259, $p$ < .001), with the gifted students showing more interest ($M$ = 19.53, $SD$ = 3.72) than the non-gifted students ($M$ = 17.26, $SD$ = 4.09). These results can be explained by the self-concept of gifted students. Cheung (2018) pointed out that self-concept is one of the most important predictors of individual interest, while Košir et al. (2016) and Metin and Kangal (2012) found that self-concept is usually higher in gifted students than non-gifted students.

The students who perceive themselves as gifted for chemistry ($M$ = 20.11, $SD$ = 3.51) also showed a significantly higher level of individual interest for learning chemistry ($t$ = 7.311, $df$ = 259, $p$ < .001) than those who do not perceive themselves as gifted ($M$ = 16.71, $SD$ = 3.89). These results might indicate that students' self-concept is not affected by other people telling them that they are gifted. It should be noted, however, that 70% of the students in the present sample who rated themselves as gifted in chemistry had already been identified as gifted.

A significant difference was found in the students' attitude towards IBL ($t$ = 2.365, $df$ = 260, $p$ < .001), with the gifted students showing a more positive attitude towards IBL ($M$ = 21.55, $SD$ = 2.57) than the non-gifted students ($M$ = 20.65, $SD$ = 3.31). The students who evaluated themselves as gifted for chemistry ($M$ = 21.79, $SD$ = 2.68) also have a significantly better attitude towards IBL ($t$ = 3.724, $df$ = 260, $p$ < .001) than the students who do not think they are gifted ($M$ = 20.42, $SD$ = 3.18). The findings of the present study are supported by those of Eltanahy and Forawi (2019), who found that gifted students have positive attitudes towards inquiry activities. The results can also be explained by the findings of Özgür and Yilmaz (2017), Eysink et al. (2015), Can and Inel Ekici (2021), and Juriševič and Devetak (2018), all of whom concluded that IBL can make learning more effective for gifted students and thus improve their attitudes towards this learning method.

A significant difference between the gifted and non-gifted students was also determined regarding their situational interest ($t$ = 2.507, $df$ = 256, $p$ = .013), with the gifted students showing a higher level of interest ($M$ = 39.16, $SD$ = 5.29) than the non-gifted students ($M$ = 37.29, $SD$ = 6.29). Similar results were found between the students who evaluated themselves as gifted or non-gifted for chemistry. The students who think they are gifted for chemistry ($M$ = 39.44, $SD$ = 5.50) showed a significantly higher level of situational interest ($t$ = 3.454, $df$ = 257, $p$ < .001) than the students who think they are not gifted ($M$ = 36.92, $SD$ = 6.08). These results are difficult to explain because there is no accessible literature on the effects of inquiry learning on gifted students' situational interest. One possible explanation could be that gifted students enjoy inquiry learning more than non-gifted students, as noted by Eltanahy and Forawi (2019), and that active participation, deeper interest in the task and engagement are factors that influence situational interest, as noted by Durik and Harackiewicz (2017) and Snětinová et al. (2018).

When comparing the students who had previous experience with IBL in school and those who did not, a significant difference was found between the groups in their autonomous motivation ($t = 2.240$, $df = 260$, $p = .029$). The students who had previous experience with IBL in school had a higher mean score ($M = 19.31$, $SD = 3.04$) than those who did not ($M = 17.88$, $SD = 4.29$). A significant difference was also found in their individual interest ($t = 2.839$, $df = 259$, $p = .005$), with the gifted students showing more interest ($M = 18.57$, $SD = 3.85$) than the non-gifted students ($M = 16.78$, $SD = 4.71$). On the other hand, no significant differences were found between the two groups in their attitudes towards IBL ($t = .931$, $df = 261$, $p = .353$), situational interest ($t = .520$, $df = 256$, $p = .604$) and controlled motivation ($t = 1.344$, $df = 261$, $p = .180$).

**Table 3**

*Summary of results regarding the third research question*

| | | Independent variables | | |
|---|---|---|---|---|
| | | **General academic giftedness** | **Self-reported giftedness for chemistry** | **Previous experience with IBL in school** |
| Dependent variables | Attitude towards IBL | $t = 2.365$, $df = 260$, **$p < .001$** | $t = 3.724$, $df = 260$, **$p < .001$** | $t = .931$, $df = 261$, $p = .353$ |
| | Situational interest | $t = 2.507$, $df = 256$, **$p = .013$** | $t = 3.454$, $df = 257$, **$p < .001$** | $t = .520$, $df = 256$, $p = .604$ |
| | Individual interest | $t = 4.599$, $df = 259$, **$p < .001$** | $t = 7.311$, $df = 259$, **$p < .001$** | $t = 2.839$, $df = 259$, **$p = .005$** |
| | Autonomous motivation | $t = 3.514$, $df = 260$, **$p = .019$** | $t = 5.196$, $df = 260$, **$p < .001$** | $t = 2.240$, $df = 260$, **$p = .029$** |
| | Controlled motivation | $t = 4.599$, $df = 246.6$, $p = .542$ | $t = -.682$, $df = 261$, $p = .496$ | $t = 1.344$, $df = 261$, $p = .180$ |

As shown in Table 3, it can be concluded that both general academic giftedness and self-reported giftedness for chemistry affect students' attitudes towards IBL, their situational and individual interest, and their autonomous motivation, while students' previous experience with IBL in school affects their individual interest and their autonomous motivation.

## Conclusion

The important findings presented in the theoretical introduction of this paper report that non-formal and informal activities have a positive impact on students' science learning. This applies not only to academically average achievers, but also to gifted students, who were the focus group of the Slovenian DiSSI project team. The focus of the present study was on the field of chemistry education.

Gifted students for chemistry usually show an interest in acquiring chemistry knowledge at a higher level than specified in the national curriculum for chemistry. Such activities may include the IBL approach in a specific context. One of the goals of the Slovenian DiSSI team was to develop educational strategies in chemistry in a non-formal learning environment. DiSSI learning modules using the IBL approach were therefore developed for implementation in a non-formal learning environment.

The present study was conducted to investigate how individual interest in learning chemistry and autonomous and controlled motivation for learning chemistry between different groups of students affect their attitudes towards IBL, situational interest and interest in science careers.

The results of the study can be summarised in several main points. The difference in students' attitudes towards IBL between the low/average/high individual interest groups is statistically significant. A significant difference was also found when comparing situational interest among the three groups with different individual interest for learning chemistry. Thus, it can be concluded that situational interest for learning with DiSSI modules may also be influenced by individual interest. The connection between the level of individual interest and the preference for the DiSSI activity can be confirmed, as students who show a higher level of individual interest have a more positive attitude towards IBL learning and show a higher level of interest in a future science-related career. Some additional results are worth highlighting. Firstly, a statistically significant difference was found in students' attitudes towards IBL between the low/average/high autonomous motivation groups. Secondly, a statistically significant difference was determined when comparing situational interest in the three groups of students with different levels of autonomous motivation. Finally, a statistically significant difference was discovered when comparing students' interest in science careers. On the other hand, when comparing situational interest, there was no significant difference between the three groups of students regarding their controlled motivation for learning chemistry. It can be summarised that, in our case, situational interest was not influenced by external factors. In contrast, it can be also concluded that, when comparing students' interest in science careers, there is a significant difference between the three groups of students with different levels of controlled motivation for learning chemistry.

There are no significant differences in attitude towards IBL and situational interest between students who participated in our "Forensic Science" workshop before and after the adaptations.

There were significant differences between students based on their general academic giftedness (group 1: gifted, group 2: non-gifted) when comparing their attitude towards IBL, situational interest for learning chemistry topics using DiSSI modules, individual interest and autonomous motivation for learning chemistry.

The same results were obtained when comparing students who considered themselves gifted for chemistry (Group 1) or non-gifted for chemistry (Group 2). There were significant differences between both groups of students when comparing their attitudes towards IBL, situational interest for learning chemistry topics using DiSSI modules, individual interest and autonomous motivation for learning chemistry.

It is also important to emphasise that students who had previous experience with IBL in school science show a significantly higher level of individual interest and autonomous motivation for learning chemistry.

In the conclusions, we have only highlighted some important findings that are useful for researchers in the field of chemistry education, as well as for chemistry teachers in primary and secondary schools.

It should also be emphasised that, in addition to the learning or teaching of gifted students, DiSSI learning modules can, with appropriate adaptations, also be targeted at students with various other characteristics, such as: (1) those who come from a lower socioeconomic status background, (2) those who belong to an ethnic or cultural background that differs from the majority in society, and (3) those with lower language skills for effective communication in the predominant language in society. From this point of view, the applied methodology of the DiSSI project and its approach to the learning and teaching of science, especially chemistry, prove to be appropriate.

### *Limitations*

The present study also highlights certain limitations. In a study of this kind, it would be useful to apply a pre-knowledge test to determine students' prior knowledge of the chemistry concepts relevant for the DiSSI activities before implementing the modules in a non-formal educational setting and then evaluate their knowledge obtained during the lab activities. This would provide a better insight into the impact the prepared DiSSI learning modules on students' chemistry concepts understandings.

Another limitation of this study was the fact that only the "Forensic Science" DiSSI module was adapted to the needs of other possible students' diversities, such as lower language skills and belonging to an ethnic or cultural environment that is different from the majority of society, but not to students with lower socioeconomic status. It would be good to apply the adaptations to all of the other DiSSI learning modules developed in this project as well. A larger sample of participants in the implementation of the learning modules would provide better insights into the problems that occurred during laboratory activities. Furthermore, in order to establish a better understanding of the difficulty of the tasks included in the DiSSI modules, upper secondary school students and non-chemistry university students would also be relevant participants in the research, as it was observed during lab work that some of the activities exceed even gifted lower secondary school students' understanding of chemistry concepts.

***Educational implications***

This study has several educational implications. First, teachers can select a DiSSI learning module, take the DiSSI box prepared for it, and thus conduct a chemistry laboratory activity in school. The developed DiSSI learning modules with the IBL approach in context can be used not only in non-formal education but also in formal education. It is also important to point out that IBL is an effective approach not only for gifted students, but also for those who are not gifted for science or chemistry with some specific adaptations of the modules that teachers can use. Finally, teachers in schools also have the option of converting DiSSI teaching modules from the guided IBL approach to a more open IBL approach for those students who find guidelines for lab work frustrating and not challenging enough.

***Further research***

Future studies could also evaluate the implementation of other adapted DiSSI learning modules. It would also be useful to evaluate the knowledge that students acquire when using DiSSI learning modules in a non-formal learning environment, when using DiSSI boxes in schools and when using adapted DiSSI learning modules.

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