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Aims & Scope

The CEPS Journal is an international peer-reviewed journal with an international board. It publishes original empirical and theoretical studies from a wide variety of academic disciplines related to the field of Teacher Education and Educational Sciences; in particular, it will support comparative studies in the field. Regional context is stressed but the journal remains open to researchers and contributors across all European countries and worldwide. There are four issues per year. Issues are focused on specific areas but there is also space for non-focused articles and book reviews.

About the Publisher

The University of Ljubljana is one of the largest universities in the region (see www.uni-lj.si) and its Faculty of Education (see www.pef.uni-lj.si), established in 1947, has the leading role in teacher education and education sciences in Slovenia. It is well positioned in regional and European cooperation programmes in teaching and research. A publishing unit oversees the dissemination of research results and informs the interested public about new trends in the broad area of teacher education and education sciences; to date, numerous monographs and publications have been published, not just in Slovenian but also in English.

In 2001, the Centre for Educational Policy Studies (CEPS; see http://ceps.pef.uni-lj.si) was established within the Faculty of Education to build upon experience acquired in the broad reform of the national educational system during the period of social transition in the 1990s, to upgrade expertise and to strengthen international cooperation. CEPS has established a number of fruitful contacts, both in the region – particularly with similar institutions in the countries of the Western Balkans – and with interested partners in EU member states and worldwide.

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Revija Centra za študij edukacijskih strategij je mednarodno recenzirana revija z mednarodnim uredniškim odborom in s prostim dostopom. Namenjena je objavljanju člankov s področja izobraževanja učiteljev in edukacijskih ved.

Cilji in namen

Revija je namenjena obravnavanju naslednjih področij: poučevanje, učenje, vzgoja in izobraževanje, socialna pedagogika, specialna in rehabilitacijska pedagogika, predšolska pedagogika, edukacijske politike, supervizija, poučevanje slovenskega jezika in književnosti, poučevanje matematike, računalništva, naravoslovja in tehnike, poučevanje družboslovja in humanistike, poučevanje na področju umetnosti, visokošolsko izobraževanje in izobraževanje odraslih. Poseben poudarek bo namenjen izobraževanju učiteljev in spodbujanju njihovega profesionalnega razvoja.

V reviji so objavljeni znanstveni prispevki, in sicer teoretični prispevki in prispevki, v katerih so predstavljeni rezultati kvantitavnih in kvalitativnih empiričnih raziskav. Še posebej poudarjen je pomen komparativnih raziskav.

Revija izide štirikrat letno. Številke so tematsko opredeljene, v njih pa je prostor tudi za netematske prispevke in predstavitve ter recenzije novih publikacij.

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Review

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Editorial

Diversity in Science Towards Social Inclusion

Working towards greater equality of opportunities means striving for the sustainability goals put forward by the United Nations, which also play a central role in European Union sustainability policy. One of the most frequently named goals can be subsumed under Sustainability Goal 4.1 to 'ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes' (UN General Assembly, 2015, p. 17) with a special focus on the appreciation of cultural diversity (4a) and educating teachers to ensure an effective inclusive education system (4c). In a wider perspective, this contributes equally to Goal 10.2: to 'empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status' (UN General Assembly, 2015, p. 21). In particular, the European Commission's expert group for science education has conceptualised responsible science education as 'inclusive in terms of gender, social, economic and cultural diversity' and, therefore, has adopted a broad definition of inclusive education.

The EU recommendation *Science Education for All* expresses the need to focus on students currently disadvantaged in science education because of poor linguistic skills, cultural and ethnic differences, lower socio-economic status, or giftedness. For this purpose, the quality of teaching should be enhanced to improve the depth and quality of learning outcomes. In addition, educators working in formal, non-formal, and informal settings should collaborate to ensure that effective measures in the science education sector are taken in a joint approach. This can increase the uptake of science studies and science-based careers to improve employability and competitiveness. Taking into account societal needs and global development, innovation and science education strategies should be connected at local, regional, national, European, and international levels.

Currently, career decisions in science are influenced by gender, class, and cultural background, as shown in numerous studies (e.g., DeWitt et al., 2011). Evidence comes from a large body of research investigating the role of socio-economic status, ethnicity, and gender in science-related career decisions. It is well documented that students with a strong socio-economic background are much more likely to choose science subjects in school. Science fields tend to be not only gendered in favour of males but also associated with white middle-class students. For example, young women with migration backgrounds could thus be facing a twofold disadvantage, being both female and belonging to an ethnic minority.

One of the main goals of science lessons is gaining content knowledge. However, science knowledge and access to this important sector of the job market are unevenly distributed. A major challenge in science education is to support every student so that he or she can learn science in the best possible way. This has been emphasised by the European Commission's expert group for science education, which stated that it 'should be an essential component of a learning continuum for all'. The expert group defined a need for 'innovative teachers' strategies to address the diversity of students'. If diversity is insufficiently addressed, this results in 1) social inequalities in the access to a wide range of well-paid jobs, leading to social tensions, 2) low-achieving students who do not acquire scientific literacy, which is central for becoming responsible citizens in our society shaped by science and technology, and 3) gifted students who cannot fully contribute to society.

The especially disadvantaged students in science are those who differ from the 'norm'. This is true for students with a lower socio-economic status, those who speak other languages at home than the language of instruction, or who belong to ethnic minorities. Unexpectedly, gifted students also tend to be disadvantaged and underrepresented in science.

One challenge for inclusive teaching becomes clear in this discussion: in most cases, interventions seek to support one disadvantaged group. Very often, this group is separated from the other students. Thus, these practices are not inclusive in the sense that all students learn together and are equally well supported.

Starting from this idea, Rachel Mamlok-Naaman, in the first paper of the issue, *Diversity and Inclusion in Science Education: Why? A Literature Review*, discusses the relevance of diversity and inclusion. The paper is based on a literature review of existing knowledge on the subject; different studies are discussed, and the author investigates why inclusion and diversity are a topic in science education.

The second paper, by Sarah Kieferle and Silvija Markic, *Language Support in a Student Laboratory for Chemistry in Secondary School*, focuses on dealing with language diversity in non-formal education. A study presented in the paper shows the way of dealing with diversity in students' language skills. This topic is important since students whose first language is not the language of instruction face difficulties in acquiring science knowledge. This has been shown, for example, in the TIMSS 2007 study and other studies, in which students who spoke the language of instruction only seldom at home achieved lower levels in science than those who spoke the language of instruction at home on a regular basis. These students have to learn science content and linguistic structures at the same time. However, not only these students perceive the language in science as difficult. Many students whose parents have little formal education are also disadvantaged, because the subject-specific languages in science are very different from everyday language.

In science education, the consideration of cultural diversity is relatively new. This means that existing teaching approaches for addressing cultural diversity are rare, and there is a lack of concrete teaching material. However, it is widely known that students from minority groups tend to be disadvantaged in science. Racism is performed in science classrooms (Sheth, 2019), and the science achievement of many ethnic minorities is significantly lower than that of students of the ethnic majority (e.g., Norman et al., 2001). Students whose parents are immigrants achieve lower scores than students whose parents were born in the country. In this issue, *Innovative Learning Activities for Ethnically Diverse Students in Macedonian Science Education*, written by a group of science education researchers from University of Skopje (North Macedonia) led by Katerina Rusevska, presents different innovative learning methods for ethnically diverse groups. Following this, *Someone Like Me: A Trial of Context-Responsive Science as a Mechanism to Promote Inclusion*, written by Jane Essex, Kirsty Ross and Ingeborg Birnie, discusses two studies that involve science activities that were designed, implemented, and evaluated to show culturally contextualised science.

The TIMSS and PISA studies showed that achievement in science is strongly linked to the students' social background, especially the parents' educational level and the socio-economic status. Researchers from the University of Limerick, Genco Guralp and Sarah Hayes, present *Non-formal Science Education: Moving Towards More Inclusive Pedagogies for Diverse Classrooms* on this issue. The study focuses on best practice examples that strengthen the science capital of students, which are applicable across various contexts of diversity.

Finally, Miha Slapničar, Luka Ribič, Iztok Devetak and Luka Vinko focus on the group of students that is often not seen as a disadvantage in *Inquiry-Based Chemistry Education Activities in a Non-formal Educational Setting for Gifted Students.* Gifted students tend to be neglected in discussions about inclusive teaching. However, these students need special attention in science teaching, and underperformance can occur if their needs are not addressed. If specialised support for these students exists, it often consists of a separation of these students in terms of ability grouping. They attend specialised classes for high-performing students or are asked to participate in a science club. Although these can be very useful strategies, they do not follow the idea of inclusive teaching. The researchers present a study that discusses the evaluation of inquiry-based science education (IBSE) learning activities from the perspective of gifted and non-gifted students. Individual interest, autonomous and controlled motivation between different groups of students, and how these activities affect their attitude toward IBSE, situational interest, and interest in science careers are presented.

Three varia papers complete this issue. Rooserina Kusumaningdyah, Iztok Devetak, Yudhi Utomo, Effendy Effendy, Daratu Putri, and Habiddin Habiddin, in *Teaching Stereochemistry with Multimedia and Hands-On Models: The Relationship between Students' Scientific Reasoning Skills and The Effectiveness of Model Type*, discuss a study on the influence of multimedia and hands-on models on university students` understanding of stereochemistry. The study concludes with the influence of different models and students' skills.

The second varia paper, by Maja Kerneža and Igor Saksida, focuses on a study of *Slovenian Language Teachers' Attitudes Towards Introducing Comics in Literature Lessons in Primary School* and shows the great need for teacher training about the value and possibilities of usage of comics in primary schools.

The last paper in this section, written by Monika Mithans, Joca Zurc and Milena Ivanuš Grmek, discusses *Perceptions of Didactic Strategies among Pupils and Teachers in Primary School* and shows that problem-based learning and research-based learning as the most commonly used didactic strategies seen both by teachers and students. However, some differences in teachers' perceptions about how they teach and students' experience of teaching are seen.

To round out the work on inclusion, a book by Jane Essex, *Inclusive and Accessible Secondary Science: How to Teach Science Effectively to Students with Additional or Special Needs*, published by Routledge in 2023, is reviewed by Elisabeth Hofer. The book can be divided into two parts: the theoretical and the practical. The book emphasises the importance of inclusive education and shows possible ways for inclusive science education, summarised after more than a decade of the author's work on this topic.

The authors of this issue and I worked on the same goal in the Diversity in Science towards Social Inclusion (DiSSI) Project, the overarching purpose of which is to contribute to the equality of opportunities in science teaching. DiSSI focuses on science learning since science knowledge is a key competence for a wide range of jobs in engineering, industrial research, and many other fields that form the heart of the economy. As defined in the EU report, this can be conceptualised as a contribution to Science Education for Responsible Citizenship. This will help teach students to shape our future responsibly based on scientific evidence, as requested in the Paris Declaration.

We hope our contribution will enrich your teaching and motivate you for further work in this field.

Silvija Markic

Acknowledgement

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Diversity and Inclusion in Science Education: Why? A Literature Review

Rachel Mamlok-Naaman[1]

In the last twenty years, there has been a consensus around the world that effective science education is vital to economic success in the emerging knowledge age. It is also suggested that knowledge of science and scientific ways of thinking is essential to participation in democratic decision-making. Students may recognise differences and advocate diversity, but assimilating those ideas requires the creation of conditions in which students can think deeply about situations that require tolerance. Schools in many countries and regions of the world are places shaped by cultural diversity. One may observe that in many schools there are social developments like migration and demographic and value change, consequently increasing the diversity of students. The issue of diversity in science education is therefore tackled according to many aspects, e.g., culture, language, scientific literacy and gender. The aim of the present literature review is to align the ERASMUS+ project Diversity in Science towards Social Inclusion with studies and views regarding diversity and inclusion in science education. The main goals of this project were to promote inclusive education and to train and foster the education of disadvantaged learners through a range of measures, including supporting education staff in addressing diversity and reinforcing diversity among education staff. Practices dealing with dimensions of diversity and inclusion in science education are developed and the partners shared the good practices that they developed.

Keywords: diversity, inclusion, chemistry language, culture, scientific literature

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Raznolikost in inkluzija v naravoslovnem izobraževanju: zakaj – pregled literature

Rachel Mamlok-Naaman

V zadnjih dvajsetih letih je bilo po vsem svetu doseženo soglasje, da je učinkovito naravoslovno izobraževanje ključnega pomena za gospodarski uspeh v nastajajoči dobi znanja. Prav tako se domneva, da je poznavanje naravoslovja in znanstvenih načinov razmišljanja bistveno za sodelovanje pri demokratičnem sprejemanju odločitev. Učenci lahko prepoznavajo razlike in zagovarjajo raznolikost, vendar je za usvajanje teh idej treba ustvariti pogoje, v katerih lahko učenci poglobljeno razmišljajo o situacijah, ki zahtevajo strpnost. Šole v številnih državah in regijah sveta so kraji, ki jih oblikuje kulturna raznolikost. Opazimo lahko, da v veliko šolah prihaja do družbenih dogajanj, kot so: migracije ter demografske in vrednostne spremembe, kar posledično povečuje raznolikost učencev. Vprašanje raznolikosti v naravoslovnem izobraževanju se zato obravnava glede na številne vidike, npr. kulturo, jezik, naravoslovno pismenost in spol. Namen tega pregleda literature je uskladiti projekt ERASMUS+ DiSSI (Diversity in Science towards Social Inclusion) s študijami in pogledi na raznolikost in inkluzijo v naravoslovnem izobraževanju. Glavni cilji tega projekta so bili: spodbujanje inkluzivnega izobraževanja ter usposabljanje in spodbujanje izobraževanja prikrajšanih učencev z različnimi ukrepi, vključno s podporo izobraževalnemu osebju pri obravnavanju raznolikosti in krepitvi raznolikosti med izobraževalnim osebjem. Razvite so bile prakse, ki obravnavajo razsežnosti raznolikosti in inkluzije v naravoslovnem izobraževanju, partnerji pa so delili dobre prakse, ki so jih razvili.

Ključne besede: raznolikost, inkluzija, kemijski jezik, kultura, znanstvena literatura

Introduction

Diversity in Science towards Social Inclusion (DiSSI) was an ERASMUS+ project initiated by Professor Silvija Markic from LMU in Germany. The main objective of the project was to promote inclusive education and training, with an emphasis on enhancing educational opportunities for disadvantaged students. This involved providing support to education staff to effectively address and strengthen diversity within education staff.

Researchers from Ireland, Germany, the UK, Slovenia and Macedonia developed a teaching approach that considers the needs of students:

- from low socioeconomic status backgrounds;
- from ethnic minorities or with cultural backgrounds that differ from the mainstream culture;
- with low linguistic skills;
- who are considered as gifted students.

The aim of the present paper is to align the DiSSI project with studies and views regarding diversity and inclusion in science education. The partners shared the good practices that they developed dealing with diversity and inclusion in science education.

There is a global consensus that effective science education is crucial for economic success in the emerging knowledge age (Mansour, 2013). Furthermore, it is believed that a grasp of scientific knowledge and thinking is crucial for active participation in democratic decision-making. Although students may acknowledge differences and support diversity, assimilating these ideas necessitates establishing conditions that enable students to engage in profound reflection on situations requiring tolerance (Mamlok, 2013).

In their 2009 publication, Lee and Luykx conducted a comprehensive study analysing the impact of racial, ethnic, cultural, linguistic and socioeconomic variability on science achievement among K–12 students, a demographic group traditionally underserved by the education system. The book starts by addressing science achievement gaps within diverse racial, ethnic and socioeconomic groups. It then outlines the methodological and other criteria employed in the research, concluding with a presentation of findings. These findings explore the correlation between science achievement gaps and various factors, including the science curriculum, instruction, assessment, teacher education, school organisation, educational policies, and students' home and community environments. The authors propose a research agenda aimed at strengthening areas where a knowledge base is urgently needed.

In many countries and regions of the world, schools have their own cultural diversity (Rüschenpöhler & Markic, 2019). In many schools, there are social developments such as migration and demographic and value change, consequently increasing the diversity of students (Stinken-Rösner et al., 2020; Lee, 2003). Rüschenpöhler and Markic (2019) investigated the concept of science capital as it relates to chemistry education. They introduced the term 'chemistry capital' to capture the characteristics that contribute to individuals' success in the chemistry domain. These characteristics may include parental knowledge of chemistry content and engagement in chemistry-related activities at home. The authors conducted a study in which they interviewed 48 secondary school students in Germany using thematic analysis. The findings indicate that chemistry capital within the home environment is not uniformly distributed. Students lacking familial connections with the mainstream conception of chemistry tend to be located in schools with lower entry requirements. However, the research also identified cases where students independently acquired chemistry capital, despite the absence of familial support. To address these entrenched inequalities, the authors advocate teaching methodologies that prioritise identity formation and that actively involve students and their parents in a dialogue about chemistry.

Considering individual science/chemistry capital, there is a concerted effort to make science education inclusive and accessible to all students, with the aim of attaining scientific literacy for every student, beyond the preparation of those inclined towards academic careers in the sciences (Holbrook & Rannikmae, 2009). The key idea is to foster scientific literacy for all students, acknowledging that environmental, political, social or historical contexts can contribute to shaping active and reflective citizens. Accordingly, the initial step towards achieving 'scientific literacy for all' involves identifying stimulating and pertinent scientific issues, contexts, problems and questions.

The PISA Framework (OECD, 2013), established by the Organization for Economic Co-operation and Development (OECD), emphasises scientific literacy as the primary objective of science education. Scientific literacy is defined as "the ability to engage with science-related issues and with the ideas of science as a reflective citizen" (p. 7). A scientifically literate individual is expected not only to possess the ability, but also the interest in engaging in informed discussions about science and technology (Eilks et al., 2014). The PISA Framework recommends skills such as the following:

- *Explain phenomena scientifically:* recognise, offer and evaluate explanations for a range of natural and technological phenomena.
- *Evaluate and design scientific inquiry*: describe and appraise scientific studies and/or experiments and propose ways of addressing questions scientifically.

- *Interpret data and evidence scientifically*: analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

Scientific literacy in our contemporary world is a multifaceted concept consisting of media literacy and the ability to use information and communication technology (ICT) (Rodrigues, 2010). Media literacy, particularly in the context of digital media, has emerged as an essential cross-curricular goal in modern society, significantly influencing educational reforms (Belova et al., 2017).

The establishment of standards in science and mathematics education is often inspired by the AAAS (1993) Benchmarks for Scientific Literacy report. The science education standards articulated by the National Research Council (1996) serve as recommendations for 'best practices'. These practices encapsulate the current vision of the content, classroom environment, teaching methods and support needed to deliver a high-quality science education to all students. More recently, the Next Generation Science Standards (NGSS, Lead States, 2013) have been developed to outline 'the best practices' for teaching K–12 science content in the United States.

Attaining scientific literacy for all has evolved into a national education goal in numerous countries (Marks & Eilks, 2009). This objective poses a challenge for science teachers and those responsible for professional development (Lee, 2004). Its achievement necessitates a reform in the way chemistry is taught in schools (Norris & Phillips, 2003). Furthermore, the shift towards incorporating socio-scientific issues (SSIs) and education for sustainable development (ESD) in the chemistry curriculum reflects a broader reshaping of goals for science education, aiming for a more critical perspective of scientific literacy (Sjöström et al., 2017).

All of the above is based on the assumption that teachers are the best professional partners to develop lesson plans that combine issues related to chemistry content knowledge (CK) and its associated professional content knowledge (PCK). Teachers are more aware than others of the diversity of students' needs, interests and abilities.

Stinken-Rösner et al. (2020) stated that environmental, political, social and historical contexts play a crucial role in fostering students' development into active and reflective citizens. Consequently, the initial stride toward achieving 'scientific literacy for all' involves identifying stimulating, captivating and pertinent scientific issues.

To sum up, it is clear that teachers are at the centre of the sphere of influence. It is therefore recommended that 'top-down' curricular procedures be avoided or reduced. Teachers need time to develop as policy-makers and to make appropriate changes (Mamlok-Naaman et al., 2018). If our aim is to achieve effective science education, we should therefore tackle the issue of diversity in science education according to many aspects, e.g., culture, language, scientific literacy and gender.

Effective science education

Saet (2021) defined inclusive education as the practice of having all children, irrespective of their differences or special needs, studying together in the same school and within the same classrooms:

> Inclusive schooling does more than teaching children maths and language skills; it provides them with a safe space to grow and learn basic life skills, such as cooperation, responsibility, and respect. (p. 1)

The consideration of student diversity is meaningful for teaching and learning science (Markic & Abels, 2014). Teachers often treat their classes as belonging to homogeneous learning groups (Taber & Riga, 2016). However, the diversity of a group should be regarded as an opportunity for every student to develop. Diverse ideas and learning strategies may serve as a source of enrichment for every student (Florian & Spratt, 2013). According to Stinken-Rösner et al. (2020):

> In order to address the diversity and different needs of all students and enable full and equal participation, barriers must first be minimised or avoided. Additionally, in an educational sense, participation is about collaboration and creating different ways or approaches to a particular learning object. (p. 31)

The barriers may be aspects such as culture, language, gender (as mentioned above) or lack of scientific literacy (Lee, 2005). Concepts and phenomena should therefore be clarified for all students, acknowledging their personal, sociocultural, affective and cognitive learning diversity (Stinken-Rösner, 2020). Erduran (2003) claimed that ineffective communication between students and teachers can result in a gap between what is taught and what is learned. In the context of science lessons, achieving alignment between teachers' understanding of a specific science topic and students' ideas about it is crucial. Such alignment indicates the accurate transmission and reception of scientific knowledge in the classroom. For instance, ensuring the incorporation of key aspects such as macroscopic/microscopic relationships and the role of modelling in establishing these relationships is essential.

Bianchini et al. (2002) claim that issues of inclusion in science and remedying inequities in the science classroom can be facilitated by integrating the history, philosophy and sociology of science into professional development programmes. Education policy and teacher education should support teachers regarding these issues. Hilferty (2008) suggests that policy changes connect teachers' work to a larger citizenship agenda. Mamlok (2021) wrote that we should:

> Strive for the attainment of a common good, which involves constant interaction among people from diverse communities and political agents who work for the betterment of the public. (p. 14)

It has been suggested that the model of professional development is one of the most effective methods to overcome the challenges that teachers face. It enables teachers to reflect on and learn about how new practices can be evolved or shaped from existing classroom practice. This is not simple, as it requires teachers to re-examine what they do and how they might do it differently. In addition, attaining challenging learning goals in science according to students' needs represents a significant change in teachers' roles. Thus, teachers must enhance their ability to cope with diversity and the inclusion of students from different cultural and socioeconomic backgrounds by using diverse teaching strategies, inter alia (Mamlok-Naaman et al., 2013). Mamlok-Naaman et al. (2007) claim that diverse teaching and instructional strategies, combined with aligned assessment tools, may address as many students as possible in a heterogeneous classroom.

In summary, teachers need to receive guidance and support throughout various teaching and implementation stages involving changes in the curriculum (Harrison & Globman, 1988; Loucks-Horsley & Matsumoto, 1999). On the one hand, it is not easy for teachers to undergo modifications that include changes in content and in the way they teach (Mamlok-Naaman, et al., 2013); on the other hand, it has been noted that teachers are typically excellent learners who are interested in trying to teach a new curriculum, as well as in improving and enriching their teaching methods (Joyce & Showers, 1983).

Cultural aspects

Pomeroy (1994) claims that there have been numerous studies dealing with the needs of diverse learners in science education that addresses multicultural, intercultural or cross-cultural education. In her paper, she mentions the two main issues in American science education, as identified by scientists, science educators and stakeholders:

a. The growing gap between the racial, ethnic and gender demographics of the population as a whole and those demographics within the scientific establishment at all levels.
b. The inability of the education system to produce students who are scientifically literate.

The major concern is the lack of policy-makers and researchers who represent the increasingly diverse interests and needs of contemporary society. Hora et al. (2019) claimed that:

One problematic feature of the influential student employability discourse in both K-12 and higher education is the widespread conception of "skills" as decontextualized bits of knowledge, ability and disposition that alone will determine a students' success (or failure) in the labor market […] This approach is evident in the ubiquitous lists of skills that college students should acquire in order to be competitive in the rapidly automating and evolving labor market of the 21st century—a narrative that we call the skills discourse in this paper […] As a result, researchers, policymakers, and postsecondary educators are increasingly focused on integrating these competencies into the college experience via curriculum, instruction, and assessment. (p. 2221)

Referring to climate and culture, Friedman (1991) examined the differences between high-burnout and low-burnout primary schools. In addition, he aimed to investigate the components of organisational climate and culture, as well as social and professional support, in order to elucidate the burnout process. Nevertheless, teachers play a key role in any change, and as such, their beliefs, attitudes and culture should be considered within the socio-cultural framework of their work (Mansour, 2013).

In another study, Lareau and Weininger (2003) attempted to evaluate the outcomes of using the cultural capital concept in English-language educational sociology. They formulated an approach emphasising the significance of scrutinising micro-interactional processes, whereby individuals strategically engage in knowledge, skills and competence, together with institutionalised standards of evaluation. The authors claim that these skills are transferable across generations and may constitute a component of the competences that students and parents draw on in their institutional encounters.

One of the conclusions that can be drawn from the literature is that political decision-makers and educational reformers must consider teachers' beliefs about the subject matter, the pedagogy in the respective domain, and the cultural norms, values and traditions – a systemic view (Markic, et al., 2016).

Language

Science educators at all levels are challenged by increasing cultural and linguistic diversity, which is a consequence of globalisation. Mortimer and Scott (2003) stated that learning science requires students to develop linguistic competence in order to participate in subject-specific discourse and engage in the social language of science using a specific vocabulary (e.g., Aikenhead & Ogawa, 2007).

Effective teaching and learning necessitate a common language for communication. As Lemke (1990) stated, learning the language of science is akin to acquiring a second language. Selinker (1972) introduced the 'Interlanguage' theory, which is a framework for understanding psycholinguistic structures and processes aimed at meaningful performance using a second language. Chemistry students must comprehend the distinctions between the macroscopic, sub-microscopic and symbolic levels (Johnstone, 1991; Talanquer, 2011; Slapničar et al., 2018).

The same terms frequently have different meanings in the academic, teaching and daily language of students (Childs et al., 2015). The language of chemistry is prevalent in chemistry lessons. Marcik and Childs (2016) coined the term 'chemish' to describe this unique language of chemistry:

> The alphabet in chemish is expressed in the symbols for the chemical elements, words are the formulae of chemical substances and sentences and syntax are chemical equations and the rules of chemical combination. (Editorial, p. 434)

Rees et al. (2021) investigated the development of chemical language usage among six non-traditional students for one to four years. In their interviews, these students were asked about their understanding of macroscopic and sub-microscopic scientific language, particularly regarding explaining specific chemical reactions. The transcribed interviews were analysed, revealing the challenges faced by students in integrating sub-microscopic language into their explanations. The students revealed a chemical interlanguage involving the blending of everyday language with scientific terminology, the interchange of terms, and the omission of terms and conversational phrases. One of the conclusions was that combining everyday language with scientific language may foster an understanding of the latter, provided that the everyday language conveys an appropriate meaning.

As previously mentioned, language may be a major hindrance to many students (Wellington & Osborne, 2009). The language of chemistry, including verbal, symbolic and diagrammatic elements, is often somewhat daunting for students to recognise, employ and interpret (Osborne, 2002). Students also struggle with understanding symbols that convey additional information, and iconic symbols are often challenging due to their representation of abstract concepts (Marais & Jordaan, 2000). Learning to understand and balance a chemical equation is similar to learn a foreign language. Actually, it is even more difficult, since the language of chemistry is abstract (Taber, 2009, p. 101).

Taber (2013) recommends exercising the use of science language in science classes, so that the students will get used to it during the learning process. In addition, textbooks that serve as curricular materials should consider this issue and be more explicit regarding abstract representations in their content (Niaz & Maza, 2011).

Laszlo's claim (2013) may be a good way to summarise this section:

> Chemistry ought to be taught in like manner to a language, on the dual evidence of the existence of an iconic chemical language, of formulas and equations; and of chemical science being language-like and a combinatorial art. (p. 1)

Gender

Significant strides have been made in advancing the empowerment of women (Mamlok-Naaman, 2021). However, persistent gender-science stereotypes in mathematics and science continue to exert an influence on this issue, potentially negatively affecting the motivation of young women to pursue STEM majors in college (Makarova et al., 2019). Women still encounter discrimination and unconscious bias, as well as contending with family demands (Mamlok-Naaman et al., 2015). The analysis of a survey entitled 'A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to measure it? How to reduce it?' identified various contributing factors. Recommendations stemming from this survey are directed at a range of stakeholders, including teachers and parents of girls in primary, secondary and higher education, as well as educational organisations, scientific unions and other global entities (Chiu & Cesa, 2020).

Blickenstaff (2005) claimed that women are still underrepresented in science disciplines, particularly in technology, engineering and mathematics (STEM), not only in the United States but also in most other countries globally. Women continue to represent a small proportion of faculty members in science and technology programmes, particularly in prestigious research institutions. Female STEM faculty members' academic careers often coincide with their child-bearing years, thus presenting challenges such as limited lab space, inadequate resources, lower salaries and fewer prestigious opportunities. According to UNESCO, these challenges make their professional lives particularly challenging, especially in the early stages of their academic careers, forcing them to grapple with discrimination, unconscious bias and family demands (Mamlok-Naaman, 2021).

There is a collective view that women in the sciences have difficulties in balancing both work and home obligations, without receiving proper support (Barnard et al., 2010). This is a huge challenge for women, so help derived from supportive sources enables them to 'gain' acceptance from male-dominated scientific fields (Mamlok-Naaman et al., 2011).

Fung et al. recently conducted a study in which they analysed existing programmes that aim to promote gender equity and inclusion in chemistry. Some 47 programmes were selected and analysed regarding their goals, the strategies used and their impact. The findings indicate that female scientists: (1) should be better recognised, and (2) should get funding for sustained networking with colleagues, e.g., conferences. The outcomes of the study were submitted to a peer-reviewed journal.

In summary, the gender gap is a societal problem (for both women and men). Female scientists can serve as role models and can inspire young female researchers. Nevertheless, narrowing the gender gap poses a significant challenge for the entire scientific community, spanning both developed and developing countries. This issue affects everyone, regardless of gender (Mamlok-Naaman, 2021).

Good practices shared by the partners

As mentioned above, the partners in the DiSSI project shared the good practices that they had developed dealing with the dimensions of diversity and inclusion in science education. The development of teaching and learning materials refers to non-formal education settings, which enable teachers to try different approaches. The teaching was based on inclusion, allowing cooperative learning while supporting the learning progress of the four disadvantaged groups of students listed in the introduction above. Each partner focused on different aspects of diversity and inclusion while referring to cultural plurality.

The partners conducted a pilot study in order to investigate the science capital of students from backgrounds with 'low' socioeconomic status. The study included inquiry-based activities, hands-on workshops, group discussions on the nature of science, and debates centred on the ethics of science.

Based on the findings, they developed and implemented learning materials aimed at increasing the science capital of these students in both formal and non-formal formats. Various sets of science outreach activities were conducted as part of the project. These activities, characterised by both formal and non-formal education, were intentionally designed to be adaptable for use in various settings beyond the traditional school environment, but they differed in terms of cultural context, the degree of open-endedness in the tasks, and the focus on the individuals involved in or affected by the science.

The activities developed included inquiry-based chemistry activities within a non-formal educational setting designed for gifted students. The main objective was to illustrate the development of learning modules and their adjustments for teaching chemistry using the Inquiry-Based Learning (IBL) approach in non-formal educational settings. After the activities were enacted, it was observed that gifted students initially held a more favourable attitude towards IBL before the module was adapted. Conversely, the non-gifted students exhibited no difference in their attitudes towards IBL, regardless of whether they had participated in the lab work before or after the Forensics Science module was adapted.

The focus of one team was on ethnically diverse students. Two types of activities were used: (1) game-based learning (escape room activities), and (2) inquiry-based learning (5E model activities). These activities were chosen because they were based on the following: (1) previous positive experiences, (2) learning through play, (3) thinking outside the box, and (4) opportunities for cooperation and socialising, including deepening friendship topics. The topics referred to ecology, gases and electrical circuits. The team developed examples of escape room puzzles, 5E (Engage Explore Explain Elaborate/Extend Evaluate) and lesson plans.

The development and implementation of the learning materials was followed by teachers' professional development and preparation, e.g., according to the Action Research model (Mamlok-Naamam & Eilks, 2012). The teams enacted their ideas through workshops with students, pre-service teachers and in-service teachers, as well as developing evaluations: pre- and post-questionnaires for students and teachers.

Table 1 summarises the good practices shared by the partners. As the table shows, each partner focused on a different component of the project.

Table 1
Good practices shared by the partners

Name of Institution	Activities
Ludwigsburg University of Education	Developing and implementing innovative concepts for language-sensitive student laboratories, with a specific emphasis on enhancing students' linguistic skills, including non-formal education, such as student laboratories.
University of Limerick	Investigating and addressing the science capital of students with a 'low' socioeconomic status at an Irish middle school, and then planning inquiry-based activities, hands-on workshops, group discussions on the nature of science, and debates centred on the ethics of science.
University of Strathclyde	Developing science interventions centred on cultural plurality and implemented by formal and informal students. The activities were designed to be adaptable for use in various settings beyond the traditional school environment.
University of Ljubljana	Developing inquiry-based chemistry activities within a non-formal educational setting designed for gifted students. The main objective was to illustrate the development of learning modules and their adjustments for teaching chemistry using the Inquiry-Based Learning (IBL) approach in non-formal educational settings.
Cyril and Methodius University, Skopje	The focus of the Macedonian team was on ethnically diverse students. They used two types of activities: (1) game-based learning (escape room activities), and (2) inquiry-based learning (5E model activities). The topics referred to ecology, gases and electrical circuits.

Summary

Addressing diversity and inclusion in science education represents a substantial challenge for teachers, who need to cultivate competencies such as personalised teaching to meet the individual needs of all students within a single classroom. Stocklmayer et al. (2010) stated that fundamental learning should occur at a pace tailored to each individual, allowing for diverse approaches. Utilising a range of both formal and informal strategies can ensure that the intellectual demands, which include an extensive array of topics in modern science, align with the learning preferences of young people in both formal and informal educational settings. Furthermore, it is anticipated that curricular materials will incorporate relevant components to cater to diverse learners' needs, potentially influencing science education and teaching practices (Belova et al., 2015).

The DiSSI project started during the Covid-19 pandemic and the corresponding restrictions for traveling. In the project meetings, which were usually short, one could notice the development of relationships of trust between partners who did not know each other very well. In addition, the ASANA project's platform management enabled an exchange of documents as well as sharing all of the other information organised by the coordinator, which was presented to and discussed with the partners during the initial meeting. The cooperation among the partners was enacted monthly by ZOOM video online meetings. Later, there were a few successful face-to-face meetings.

Pre-service and in-service teacher preparation on using the DiSSI approach for inclusive science teaching was provided to implement the concept's non-formal education. In addition, the DiSSI approach was implemented in different school curricula and beyond, through strong partnerships and networks with teachers, school principals and policy-makers.

It is suggested that the main impact aimed for was better social inclusion of different disadvantaged groups in science. The goal was to engage these groups with science and to convince more students to consider science as part of their self-identity. It is suggested that the present project managed to develop and implement good practices to deal with diversity in science education, using an approach targeting multiple cultures with a variety of needs. All of the partners referred to diversity and inclusion in developing and implementing their diversity programme.

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Language Support in a Student Laboratory for Chemistry in Secondary School

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Throughout the world, schools are visited by students with different native languages. Therefore, the linguistic competencies of the students are diverse. Dealing with this diversity is a great challenge for teachers in general, including in science subjects. To face this challenge, all institutions involved in education should adapt their teaching and learning to linguistic diversity to foster student's language competencies. Non-formal education, such as student laboratories, could enhance formal chemistry education and support students in learning the subject's contents and acquiring language competencies. To this purpose, language-sensitive and language-supportive learning settings for different chemical topics and contexts are developed to enable all students to participate actively and foster language competencies. The learning settings are implemented and evaluated at the Ludwigsburg University of Education (Germany) using a cyclical approach based on Participatory Action Research. Data from 147 students from seven learning groups of various grade levels and school types were collected before and after they experienced the work in student laboratories. The focus was on students' situational interests and their views on offered language-sensitive and language-supportive methods, tools, and activities. The data shows that the approach has a positive effect on students' situational interest. Methods that were especially helpful for the students are filtered. On this basis, implications are drawn for the application to other non-formal education offers.

Keywords: chemistry education, language-sensitive, secondary education, student laboratory

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Jezikovna podpora v laboratoriju za učence za kemijo na predmetni stopnji osnovne šole ter v srednji šoli

Sarah Kieferle in Silvija Markic

Po vsem svetu šole obiskujejo učenci z različnimi maternimi jeziki. Jezikovne kompetence učencev so tako raznolike. Spoprijemanje s to raznolikostjo je velik izziv za učitelje na splošno, tudi pri naravoslovnih predmetih. Da bi se spoprijeli s tem izzivom, bi morale vse ustanove, vključene v izobraževanje, prilagoditi poučevanje in učenje jezikovni raznolikosti ter tako spodbujati jezikovne kompetence učencev. Neformalno izobraževanje, kot so laboratoriji za učence, bi lahko okrepilo formalno izobraževanje o kemiji ter pomagalo učencem pri učenju vsebin predmeta in pridobivanju jezikovnih kompetenc. V ta namen se za različne teme in kontekste s področja kemije razvijajo jezikovno občutljiva in jezikovno podporna učna okolja, ki vsem učencem omogočajo aktivno sodelovanje in spodbujajo jezikovne kompetence. Učne okoliščine se izvajajo in evalvirajo na Pedagoški univerzi v Ludwigsburgu (Nemčija) z uporabo cikličnega pristopa, ki temelji na sodelovalnem akcijskem raziskovanju. Podatki 147 učencev iz sedmih učnih skupin različnih razredov in vrst šol so bili zbrani, preden so izkusili delo v laboratorijih za učence, in po tem. Poudarek je bil na situacijskih interesih učencev in njihovih pogledih na ponujene jezikovno občutljive in jezikovno podporne metode, orodja in dejavnosti. Podatki kažejo, da pristop pozitivno vpliva na situacijski interes učencev. Metode, ki so bile za učence še posebej koristne, so odbrane in posebej izpostavljene. Na tej podlagi so podane implikacije za uporabo v drugih ponudbah neformalnega izobraževanja.

Ključne besede: pouk kemije, jezikovna občutljivost, izobraževanje na predmetni stopnji osnovne šole, srednješolsko izobraževanje, laboratorij za učence

Introduction

Throughout the world, schools are visited by students with different native languages and linguistic competencies. Those linguistically heterogeneous students are confronted with the monolingual habitus in school (Gogolin, 2013). Dealing with this linguistic diversity is a great challenge for learning and teaching in school. Especially in science, such as chemistry, because the language used for teaching and learning chemistry content is quite different from everyday language (Markic et al., 2013). This results in various challenges for learning and teaching chemistry that need to be overcome. One of the difficulties students have to deal with in learning and teaching chemistry is the multi-layered and complex language that uses many technical and multisyllabic terms. In addition, using symbolic and mathematical aspects, as well as using diagrams and structures, often leads to comprehension problems (Childs et al., 2015). Studies like PISA (OECD, 2019) emphasise the relevance of language in science education and the disadvantages for students with a migration background in the German education system, particularly affected by learning in a second language (Lynch, 2001). Suggestions for dealing with students with different language competencies are given. There are language-sensitive (methods, tools, and activities that support students to use the language of instruction because they are second language learners, for example) and language-supportive (methods, tools, and activities that support students to develop linguistic competencies like using technical terms or specific grammar) methods, tools and activities that are effective in science education, in general, and in chemistry education, in particular (e.g., Childs & Ryan, 2016; Lee, 2005; Leisen, 2010; Markic et al., 2013). Nevertheless, to face this challenge, teaching and learning in schools are often insufficient. Non-formal education, like student laboratories, can complement the teaching and learning of chemistry in schools and support students in developing linguistic competencies. As part of the ERASMUS Plus project 'Diversity in Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity – DiSSI', Ludwigsburg University of Education (Germany) is developing, implementing, and evaluating language-sensitive and language-supportive learning settings for student laboratories in chemistry for secondary school students.

Theoretical framework

Non-formal learning takes place outside of school in an open and unrestricted setting. It is structured, organised, and oriented towards the educational curriculum (Coll et al., 2013). Non-formal learning has both characteristics of formal learning at school and informal learning in students' leisure time (OECD, 2012). In science lessons, non-formal learning opportunities are often used to increase students' interest and motivation for science (Röllke & Großmann, 2022). For example, studies show that science-related non-formal activities have been associated with better student performance, increased student belief in their ability to solve science problems, and greater enjoyment of science learning (e.g., OECD, 2012; Rennie, 2014). In non-formal education programmes, such as school laboratories, students have the opportunity to engage with scientific topics independently as part of active forms of learning (Euler et al., 2015). Non-formal education also offers many opportunities for research. The student laboratory can be used for the development, implementation, and evaluation of scientific-didactic concepts (Guderian & Priemer, 2008). This includes the development of innovative teaching and learning methods and materials with potential for adaptation to everyday science teaching in schools (Affeldt et al., 2017).

A study by Brandt (2005) shows that even a single visit to a student laboratory has a significant positive short-term effect on students' self-concept and students' intrinsic motivation for the subject of chemistry. However, these effects can only be recognised for a short time after visiting the student laboratory (Engeln,2004; Brandt, 2005). Student laboratories are generally very well suited to foster students' interest in science and technology (Brandt, 2005; Engeln, 2004). However, this effect depends on various factors, such as students' age or their general interest in the subject or the topic (Brandt, 2005; Engeln, 2004). Furthermore, Guderian (2007) and Engeln (2004) find that the current interest of students develops positively, especially if there was already a positive attitude before the visit.

Accordingly, several factors influence the effectiveness of student laboratories. It seems that if student laboratories have positive effects on students in terms of interest, motivation, or even their self-concept, it depends not least on the design of the learning setting and the learning situation that is provided. Röllke and Großmann (2022) show that variables such as the perception of autonomy and competence have a significant influence on the intrinsic motivation of students in an out-of-school laboratory. These variables can be influenced by the design of the non-formal education offered. In addition, they were able to show that the students' pre-visit preparation for the student laboratory has an impact on their intrinsic motivation. Thus, there is a need for student laboratories that are structured in such a way that all students can benefit from them as much as possible. In this context, learning settings should be designed to allow as many students as possible to work independently and successfully on scientific topics. Suggestions for the design of student laboratories that have proven successful in heterogeneous learning groups exist. Affeldt et al. (2015) suggest multi-differentiated learning settings for student laboratories to enable all students to access and learn scientific content. The development of contextualised learning settings is based on a didactic model that takes into account the different personal interests of students, their different cognitive abilities, and their heterogeneous linguistic competencies (Affeldt et al., 2015).

Putting the focus on diversity and inclusion in school, various projects and studies in Germany (e.g., Affeldt et al., 2015; Groß & Reiners, 2012; Raguse et al., 2013; Scholz et al., 2016; Stäudel et al., 2007) have shown positive effects for student laboratories. Groß and Reiner (2012) investigate alternative forms of documentation for experimentation in heterogeneous groups in their study. The implemented forms of documentation are mainly not based on reading and writing texts but focus on pictures, video, and audio notes. This study shows that video documentation is particularly suitable for documenting experimentation in heterogeneous groups. Scholz et al. (2016) show in their study that pictures and pictograms are particularly suitable as supporting tools and differentiation for inclusive student laboratories when there is the highest possible correspondence between the picture and the real object. Graded tip cards have a great potential for differentiation during experimentation in student laboratories (Affeldt et al., 2019). These cards foster communication between students when doing experiments in small groups. By using them, students more frequently discuss and exchange their ideas on how to experiment. This exchange particularly supports students in doing experiments independently (Affeldt et al., 2019).

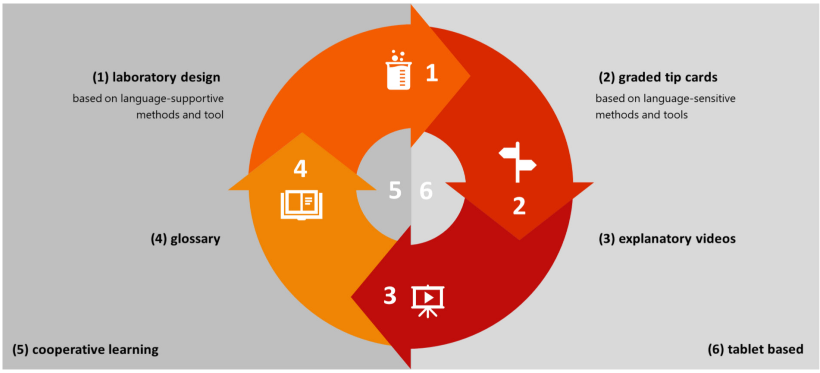
Two aspects that were shown to be particularly successful for teaching and learning chemistry in linguistic heterogeneous groups are the design of language-sensitive and language-supportive learning material (Affeldt et al., 2017) and the presentation of chemical content by contexts related to everyday life (Mamlok-Naaman & Mandler, 2020). Thus, for student laboratories that are focused on language-sensitive materials, a range of language-sensitive methods, tools, and activities need to be identified and evaluated as effective. Studies have shown that single methods, tools, and activities are applicable for language support during experimentation in student laboratories. Kieferle and Markic (2023) unite these positive findings and develop an effective connection between the evaluated methods to support students in dealing with language and to foster the development of language competencies to enable the active participation of all students during experimentation. A pedagogical approach for language-sensitive and language-supportive learning settings for student laboratories that enables all students' active participation during experimentation is developed in the present study from the perspective of the developers and tutors.

Learning Settings for a Student Laboratory Addressing Linguistical Difficulties

The present study was conducted in the context of the student laboratory at Ludwigsburg University of Education (Germany), which focuses on diversity in students' linguistic competencies. In this context, three learning settings (a mystery on substances and separation processes, a learning company on acidic and alkaline solutions, and planning a school trip on alkanols) are developed, implemented, and evaluated with two aims: 1) the development and implementation of a student laboratory that enables active participation of all students and 2) the generation of motivating learning settings for student laboratories that support secondary school students in conducting experimentation and developing language competencies. The development of the language-sensitive learning settings for the student laboratory is based on a cyclical process of development, implementation, evaluation, and adaptation oriented on Participatory Action Research, according to Eilks and Ralle (2002). More information on this can be found in the work of Kieferle and Markic (2023). The present paper focuses on the second aim. To achieve this, learning settings and language-sensitive learning materials were evaluated, focusing on the individual language-sensitive methods, tools, and activities and students' situational interests.

Students in a learning group differ not only in their language competencies; some students have mixed abilities, while others have special needs (Gardenswartz et al., 2010). Therefore, chemistry education has to deal with different language competencies and great heterogeneity (Childs et al., 2015). Thus, the development of language-supporting learning settings is based on methods, tools, and activities of language-sensitive teaching and includes opportunities to differentiate the chemical content and experimentation. Figure 1 shows the combination of approaches used for the learning settings for the student laboratory.

Figure 1
The approach of linguistic support in the student laboratory



The methods, tools and activities shown in Figure 1 enable differentiation in the demand of the content and language support of the students during experimentation using:

1. A laboratory design based on language-supportive methods and tools: We follow the idea 'content first, language second', which means that, first, students learn the fundamental concept in everyday language, then the scientific terms for the phenomenon are added (Childs & Ryan, 2016). In concrete terms, this means that the laboratory equipment is labelled and illustrated, and the learning material and support offers are marked with symbols. Students receive introductions to the context and information about the task via short videos. Longer text sequences are generally avoided.
2. Graded tip cards based on language-sensitive methods and tools: Each experiment is provided with graded tip cards that can be used individually by the students. Differentiation within a learning group (Markic et al., 2013) in the demand of their work and learning tempos is thus enabled (Städel et al., 2007). The graded tip cards are structured in steps that range from small hints to fully structured instructions. Thereby, implementations, observations, and findings could be supported individually. The graded structure of the tip cards allows the answering of complex scientific issues step by step without lowering the requirements in general (Affeldt et al., 2019). All graded tip cards are designed with language-sensitive methods and tools, according to Markic et al. (2013) and Leisen (2015). Specifically, visual aids, picture sequences, sentence starters, block diagrams, and sentence patterns are used to support

students in carrying out the experiment or formulating their observations and findings. In concrete terms, visual tools, sequences of pictures, beginning of sentences, block diagrams and sentence patterns are used to support students in performing the experiment or to formulate their observations and findings.

3. Explanatory videos: The short videos give information about important chemical content. Students can use explanatory videos individually so that differentiation within the learning group is possible. Explanatory videos are suitable for getting information to a similar extent as text sequences (Reinke et al., 2021). The advantage of explanatory videos is that they trigger positive emotional reactions in students, which increases motivation and interest in learning (Findeisen et al., 2019; Morris & Chikwa, 2014).
4. A glossary: The glossary contains short descriptions of technical terms (e.g., hypothesis) or short explanations of scientific methods (e.g., filtration). Since there are often concepts behind the technical terms used in chemistry, the use of a dictionary is usually not sufficient to support students, especially those who speak German as a foreign language. A glossary with well-chosen key terms, which also includes pictures, for example, and links the term to the concrete concept, has proved helpful (Miller, 2009).

In addition, the learning settings are developed using a tablet-based and cooperative approach.

5. Tablet-based: All work tasks, experimental instructions, and the contextualisation and organisation of the learning settings are designed digitally. Students use tablets to write their lab reports. The tablet is used as a synchronous, easy-to-use, and multifunctional experimental tool. It allows several sensory channels to be operated simultaneously and as needed (Huwer et al., 2018). The use of tablets in chemistry education has a positive effect on students' motivation (Rikala et al., 2013) and is also a differentiation possibility that is seen as very attractive by all students in an inclusive learning group (Greitemann & Melle, 2020).
6. Cooperative learning: The learning settings were developed with a special focus on communication and interdependent support between students. As part of the learning settings, the students are confronted with different problems and thinking tasks, which they have to solve together using the cooperative method of 'think/pair/share'.

Research Question

Students' opinions are critical for the effectiveness of forms of non-formal education like a student laboratory. In the sense of triangulation, the present study evaluates the learning settings and a pedagogical approach developed and presented by Kieferle and Markic (2023) from the student's perspective.

Therefore, this study is guided by the following research questions:

1. Which methods, tools, and activities are suitable for language-supportive learning settings for a student chemistry laboratory?
2. What influence do the language-supportive learning settings have on student's situational interest?

Methods

For the purpose of the present study, data from students who visited the student laboratory at the Ludwigsburg University of Education, Germany, over six months are collected. The study has a pre-post design.

Sample

The survey is carried out in seven learning groups from different comprehensive schools and secondary modern schools from different regions in southwestern Germany with a total of 147 students; 52.20% of the participating students are male, 44.90% are female, 1.40% are gender-diverse, and 1.40% are without indication. The schools were from urban (87.5%) and rural (12.5%) areas and were also attended by students with first or second-generation migration backgrounds. A total of 87.70% of the students were born in Germany, and 12.30% were born in another country. Regarding language, 33.30% of the students speak German as a native language, 10.10% speak German and one other language as a native language, and 56.50% speak German as a second or foreign language. 0.1% did not indicate their native language. Thus, more than half of the students speak the language of instruction (German) as a second or foreign language.

Before data collection, the approval of parents and students was requested. All students were informed of their right to withdraw from the study.

Instruments

For the purpose of generating quantitative data, a student questionnaire in pre-post design is used that contains items that are established in their respective field (situational interest and use of graded tip cards). The questionnaires consist closed-ended (Yes/No) and Likert-scaled questions. Additionally, an open-ended question is given.

a) The pre-test questionnaire consists of two parts:
   i) The first part collects general information on the participants. The students were asked for their age, gender, country of birth, and native language.
   ii) The second part consists of 5 closed-ended questions about students' experience of dealing with graded tip cards (Affeldt et al., 2019).

b) The post-test questionnaire consists of two further parts:
   iii) The third part is comprised of 10 Likert items (5-step). The items refer to students' situational interest and one open-ended question about the three things that were most interesting to students during the work at the student laboratory on that day (Chen et al., 2001).
   iv) The main part of the questionnaire consists of 30 Likert items (4-step). The students are asked about the use of the explanatory videos (4 Likert items), language support by using the glossary and the labelled workstations (4 Likert items), and the experience of working with graded tip cards (22 Likert items and 2 items based on closed-ended questions (Affeldt et al., 2019).

Research Design

The development of language-sensitive and language-supportive learning settings for the students' laboratory is based on Participatory Action Research (Eilks & Ralle, 2002). In a cyclical process consisting of development, implementation, evaluation, and adaptation, quantitative data is generated in each cycle.

Data Analysis

a) Pre-test questionnaire:
   ii) The Likert items are analysed with descriptive statistics based on relative frequency to make conclusions about the student's previous experiences on work with graded help cards.

b) Post-test questionnaire:
   iii) The 5-step Likert items referring to the situational interest items are analysed using descriptive statistics. A frequency statistic is carried out to make conclusions about the students' situational interests. The data of the open-ended question are categorised and sorted according to frequency of mention to show in more detail where the students' interests focus mainly.

iv) The 4-step Likert items and the closed-ended questions referring to the individual support offers are analysed using descriptive statistics. For the analysis, items were grouped into categories so that more specific conclusions could be made about the use and the impression of the students regarding the individual support offered. A frequency statistic was calculated for each item so that the trends are clearly shown.

Results

a) Pre-test:

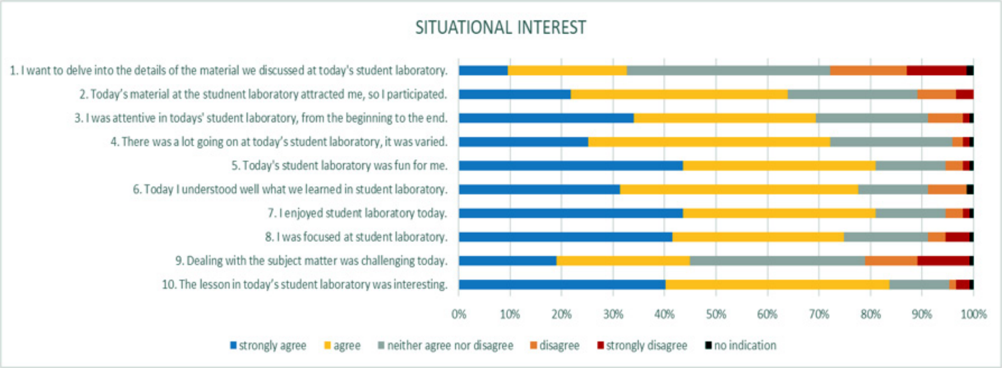
The data collected in the pre-test questionnaire show that more than half of the students in this group (69.6%) did not use graded tip cards in chemistry lessons prior to the visit to the student laboratory.

b) Post-test:

Figure 2 shows the evaluation of the items concerning students' situational interest in doing experiments in the student laboratory. The results show clearly (Figure 2; Items 5 and 7) that most of the participating students had fun during the work in the student laboratory. 80.2% stated that they can strongly agree or agree with the statement 'I enjoyed student laboratory today', and 80.9% stated that the visit to the student laboratory was fun for them. It should be highlighted here that not only 83.6% of the students stated in item 10 (Figure 2) that they found the student laboratory interesting, but 77.6% also stated in Item 6 that they understood what they were doing there.

Figure 2

Results concerning students' situational interest



The results of the open-ended question, in which the students had the opportunity to indicate three things they liked the most in the visit to the student laboratory (students N=123), the most frequently mentioned (100 mentions) were the chosen contexts and individual experiments, for example, 'the story' (S62) or 'the skin care products' (S106). Students often mentioned doing experiments (49 mentions) in general and the laboratory and laboratory clothing (40 mentions) in particular. Statements that can be categorised as inquiry-based learning (39 mentions) were also frequently mentioned. In particular, students mentioned 13 times that they most liked the results of the experiments, for example, 'the comparisons' (S125), 8 times working independently, and 7 times they mentioned inquiry, for example, 'find out what the problem is' (S101).

During the work in the student laboratory, graded tip cards were used by more than half of the students (62.2% said they had used them) in general. 45.5% of the students indicated that they used at least one card in each experiment. More than half of the students only decided to use a card when they were completely helpless in their work (63.4% strongly agreed or agreed to the statement 'I only decided to use a tip card when I was completely stuck'). If they used a tip card, they decided to do so with the team members (57.7% strongly agreed or agreed to the statement 'I decided to use the tip cards with my classmates').

The results show that 60.3% of students could not do the experiments without the help of graded tip cards. That is in line with the agreement of 55.8 % of students, which indicates that they were able to do the experiments better with the tip cards marked with test tubes (cards to support the performance) (Figure 3; Item 4). When students decided to use a tip card, 43.6% of them always took the first card first, worked with it and then took the second tip card (strongly agreed or agreed to the statement 'I always took the first tip card first, worked with it and then took the second tip card'); 46.1% of the students do not use the graded tip cards in this way. Here, the results showed that only 27.0% of the students read the first tip card and then immediately took the second one (strongly agreed or agreed to the statement 'We read the tip cards first and then immediately took the second one').

Figure 3

Results concerning students' opinion on the use of graded tip cards

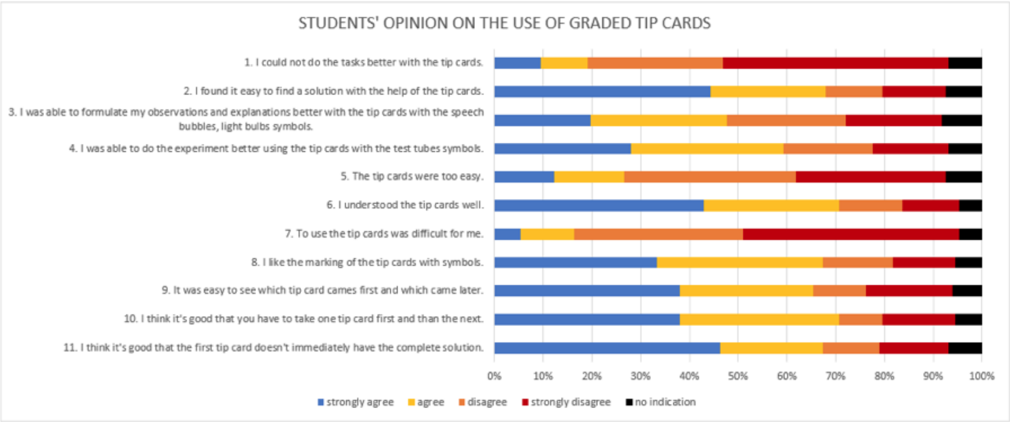
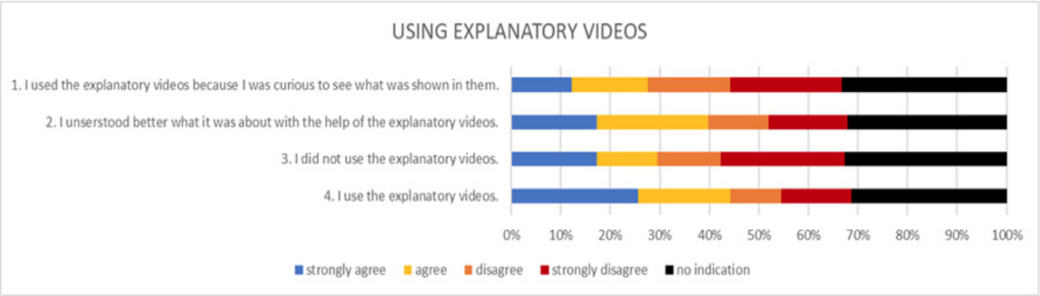


Figure 3 shows the results for students' opinions on the use of the graded tip cards. Just a few students mentioned difficulties with the use of differentiated and graded tip cards (Figure 3; Item 7). More than two-thirds of the students stated that they could do the task better with the tip cards (69.9% disagree or strongly disagree item 1). This is consistent with the 66.7% of students who understood the graded tip cards well (Figure 3; Item 6) and the 64.1% who easily found a solution using the cards (Figure 3; Item 2). Only a few students (22.4%) disagreed that it was beneficial to take the tip cards one after the other (Figure 3; Item 10) and that the first tip card did not immediately present the complete solution (24.4%) (Figure 3; Item 11). Furthermore, the results show that most students liked to have the chance to do the experiment without any help (79.5% strongly agreed or agreed to the statement 'I think it's good to have the chance to do the experiment without help').

Figure 4 shows the evaluation results referring to the explanatory videos. The high percentage of no indication is due to the fact that 32 students visited a learning setting which did not contain explanatory videos. The sample of students who had the opportunity to use explanatory videos includes 106 students; 44.2% of those students stated that they used offered explanatory videos during their work (Figure 4; Item 4). For 39.7% of students, watching the video resulted in a better understanding of the topic (Figure 4; Item 2).

Figure 4

Results concerning the use of explanatory videos



Further results referring to the labelled workstations and the glossary show that they supported students in dealing with technical terms; 66.0% of students strongly agreed or agreed to the statement, 'The labelling of the workstations with the equipment made it easier for me to use the lab equipment'. In addition, almost half of them (46.8%) found that the glossary was helpful in understanding difficult terms (strongly agreed or agreed to the statement 'I found the glossary helpful to understand difficult terms').

Discussion

Non-formal forms of education, like student laboratories, are often used, especially in science education, to help students become more interested and motivated in science. Therefore, the perception of autonomy and competence has a significant influence on students' intrinsic motivation in an out-of-school laboratory (Röllke & Großmann, 2022). The results of the study presented in this paper support the assumptions of Röllke and Großmann. The high amount of students' feedback relating to the context of the learning settings, the laboratory itself, and the laboratory clothing suggests the potential of student laboratories. The positive feedback regarding the inquiry-based learning approach shows that perceived autonomy is important for students' situational interests.

In this study, we focussed on students' linguistic diversity and wanted to determine which methods, tools, and activities of language-sensitive and language-supportive teaching are appropriate for student laboratories to enable all students to experiment autonomously and what influence language-sensitive learning settings have on students' situational interest.

In the context of this study, different types of language-sensitive and language-supportive support (graded tip cards, labelled workstations, glossary, and explanatory videos) are implemented and evaluated from the side of the users. With regard to the effectiveness of the support offers it can be said that many of the learners assessed graded tip cards as motivating them for independent experimental work and as supporting them in dealing with the experiments without any help from a supervisor in the laboratory. This is in line with the findings of Stäudel et al. (2007) and Affeldt et al. (2019), who suggested that graded tip cards can have a positive influence on students' autonomy during experimental work. However, it should be noted that approximately three quarters of the students used the graded tip cards for the first time. On the one hand, the discussion can be about whether this is the effect of working with something new; on the other hand, the usefulness of the graded tip cards is more than obvious in the results. Thus, we can, in particular, agree with Affeldt et al. (2019) that the graded tip cards have the potential to challenge and support communication among the students in small group work and promote discussion about ideas, for example, to conduct experiments. In particular, performing the experiments is supported by graded tip cards, which are evaluated as helpful and positive by students. A majority of students stated that they prefer doing experiments without any support. This point is supported by other studies, which also show that students particularly appreciate independent and cooperative learning settings (Juntunen & Aksela, 2013). However, participants still used the graded tip cards offered. This shows that students' autonomy in decision-making if and when using the offered support for their learning process is evaluated as extremely positive. This is especially true considering the fact that the students were not experienced in this kind of work, and there was less time to explain the methods compared to a classroom situation.

The results show that language-sensitive and language-supportive methods, tools, and activities such as explanatory videos can foster a better understanding of the chemical content behind the experiments and that glossaries help students deal with technical terms.

Illustrated and labelled workplaces were seen as particularly helpful in dealing with laboratory equipment students. This is in line with the finding of Scholz et al. (2016), who showed that pictures and pictograms are particularly appropriate as supporting tools and differentiation for an inclusive student laboratory when there is the highest possible correspondence between the figure and the real object.

In conclusion, the opportunity to decide individually if and in which amount of support is used is especially well accepted by students. At this point, we can assume that the combination of different support opportunities, in particular, has a positive influence on situational interest and finally results in a positive experience in the student laboratory and for students learning chemistry. The range of graded tip cards, explanatory videos, illustrated workplaces, and the glossary make it possible to support the students individually in terms of both the type and the intensity of support. A particular advantage here is that there is no need to use any support offered. The results also show that 79.5% of students liked autonomy when choosing whether they wanted to use one of the support offers. Most important, however, is that this study supports the results of Kieferle and Markic (2023) that the offered methods and tools in combination do support students' active participation in work in the student laboratories. Thus, in terms of triangulation, the combination of different methods and tools can be seen as secure. The student's view of the different support offers confirms our conclusion that direct, simple, and individual support is particularly beneficial and motivating during experimentation. The freedom of choice and autonomy also have a positive effect on students' situational interest in student laboratories. Doing experiments in small groups can be supported in a non-formal setting with the help of the above-mentioned support opportunities and enables all students to deal with the learning material actively.

Conclusions

The methods and tools used in student laboratories for language support and promotion of the development of language competencies of students can be adapted to different learning contexts and used in different learning situations based on their flexible structure. For example, the language-sensitive and language-promoting approach is not dependent on the context and content. Therefore, the context can be adapted to students' age levels, and the content can be adapted to students' learning levels or school type. The explanatory videos and the graduated tip cards make it possible to use the learning settings with or without students' previous experience with chemical content or inquiry-based learning. The DiSSI approach for language-sensitive and language-supportive work presented here grounds on a combination of different methods, tools, and activities and can be used in other non-formal education offers with various learning settings. Thus, many different learning settings in non-formal education offers, such as museums, laboratories, or science centres, can be designed in such a way that they are language-promoting and language-supporting.

The language-sensitive and language-supportive approach can also be used in formal teaching in schools. The student laboratory can act as a link in this process. On the one side, teachers can use a visit to the student laboratory as a kind of 'in-service teacher training' while learning more about new tools and methods, which she/he can adapt to their teaching. On the other side, teachers can also learn more about the usage of language and the meaning of diagnostics to better understand their students.

The presented study only encompasses a small sample, which means it cannot be considered representative. Nevertheless, it is an example of the practical implementation of language-sensitive and language-promoting approaches that need to be enhanced.

Based on the results presented here and also in Kieferle and Markic (2023), we suggest the involvement of pre-service chemistry teachers in the work of student laboratories that implement the DiSSI approach. Thus, pre-service chemistry teachers will not only theoretically learn about language-sensitive and language-supportive teaching and learning but experience them in practice. Additionally, tutoring in a student laboratory offers a chance to observe the work of students more in detail compared to the classroom situation in schools. Here, the work of smaller but also different groups is in focus.

Acknowledgement

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Innovative Learning Activities for Ethnically Diverse Students in Macedonian Science Education

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A game-based approach is widely used to increase students' motivation through their active participation, whereby research is interwoven with fun and competition is incorporated with cooperation. Working in teams or groups encourages students to exchange their opinions, to try to find solutions together or to win a game. In this way, they learn and improve skills such as collaboration and responsibility. Several activities involving the 5E model as part of inquiry-based science education and an escape room as part of game-based learning were used in science classes (chemistry, biology and physics). The activities were designed on three different topics – gases, ecology and electrical circuits – within the project "Diversity in Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity". The activities focused on the students' self-concept towards science, interest in the subject, motivation and career aspirations in STEM, as well as the effectiveness of the implemented activities. The study aimed to assess the potential advantages of implementing activities in an ethnically diverse environment, benefiting both students and teachers. Pre- and post-questionnaires were designed and distributed to 190 students from various primary and secondary schools in Macedonia. The present paper provides an overview of game-based activities as well as a brief analysis of the pre- and post-questionnaire responses from students, focusing on the topic of ecology.

Keywords: game-based activities, ecology, escape room, ethnically diverse classroom, science education

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Inovativne učne dejavnosti za etnično raznolike učence v makedonskem naravoslovnem izobraževanju

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Pristop, ki temelji na igrah, se pogosto uporablja za povečanje motivacije učencev z njihovim aktivnim sodelovanjem, pri čemer se raziskovanje prepleta z zabavo, tekmovalnost pa s sodelovanjem. Delo v ekipah ali skupinah učence spodbuja, da izmenjujejo svoja mnenja, poskušajo skupaj poiskati rešitve ali zmagati v igri. Tako se učijo in izboljšujejo spretnosti, kot sta sodelovanje in odgovornost. Pri pouku naravoslovja (kemije, biologije in fizike) je bilo uporabljenih več dejavnosti, ki so vključevale model 5E kot del na raziskovanju temelječega naravoslovnega izobraževanja in sobo pobega kot del na igri temelječega učenja. Dejavnosti so bile zasnovane na tri različne teme – plini, ekologija in električna vezja – v okviru projekta DiSSI (Diversity in Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity). Dejavnosti so se osredinjale na samopodobo učencev v odnosu do naravoslovja, ter zanimanje za predmet pri učencih, njihovo motivacijo in poklicne želje na področju STEM ter na učinkovitost izvedenih dejavnosti. Namen študije je bil oceniti potencialne prednosti izvajanja dejavnosti v etnično raznolikem okolju, ki koristijo učencem in učiteljem. Pripravljeni so bili vprašalniki pred izvedbo dejavnosti in po njej; razdeljeni so bili 190 učencem iz različnih osnovnih in srednjih šol v Makedoniji. V tem prispevku sta predstavljena pregled na igri temelječih dejavnosti ter kratka analiza odgovorov učencev pred izpolnitvijo vprašalnika in po njej, pri čemer se osredinjamo na temo ekologije.

Ključne besede: na igri temelječe dejavnosti, ekologija, soba pobega, etnično raznolik razred, naravoslovno izobraževanje

Introduction

As education continues to evolve, innovative approaches to teaching and learning are gaining traction. One prominent trend in education is the integration of educational games, which leverage the power of technology and gamification to enhance student engagement and promote effective learning experiences. Educational games have proven to be highly engaging for students, capturing their attention and motivating active participation in the learning process (Gentry et al., 2019; Hakulinen & Auvinen, 2014; Smiderle et al., 2020; Tvarozek & Brza, 2014; Yu et al., 2020). Research by Connolly et al. (2012) demonstrated that educational games promote higher levels of engagement compared to traditional instructional methods. The immersive and interactive nature of games keeps students actively involved, leading to increased interest and a deeper investment in learning.

Numerous studies have indicated that educational games can enhance learning outcomes across various subject areas. For instance, a meta-analysis by Wouters et al. (2013) examined the impact of educational games on learning outcomes and found significant positive effects on knowledge acquisition, skill development and retention. The interactive nature of games enables students to apply their knowledge, engage in problem-solving and make connections between abstract concepts and real-world scenarios, leading to deeper understanding and improved learning outcomes.

Educational games often require students to think critically, analyse information and solve complex problems within the game's context. A study by Gee (2005) highlighted the fact that games provide opportunities for learners to engage in critical thinking, strategic planning and decision-making. The iterative nature of gameplay encourages students to experiment, learn from failures and develop effective problem-solving strategies, fostering the development of valuable skills applicable beyond the game environment. Furthermore, games provide immediate feedback, allowing students to learn from their mistakes, experiment with different strategies and refine their understanding of scientific principles (Young et al., 2012).

Many educational games incorporate multiplayer or cooperative modes, promoting collaboration and social interaction between students. Research by Dondlinger (2007) showed that collaborative game-based learning environments foster positive social interactions, improve communication skills and enhance teamwork abilities. Students learn to work together, share knowledge and negotiate solutions, preparing them for collaborative work settings in the future. Collaborative educational games can enhance student learning and promote positive attitudes towards the subject matter (Stojanovska, 2021).

Game-based learning has gained significant attention as an innovative approach to education, particularly in science classrooms. This type of learning engages students emotionally, making learning memorable and increasing the likelihood of long-term retention of scientific knowledge (Plump & Meisel, 2020). It is well known that games, due to their nature, stimulate student interest. Incorporating interactive and immersive game elements captivates students' attention, fostering curiosity and motivation to explore scientific concepts (Annetta et al., 2009). Many science games incorporate competitive and collaborative elements, encouraging healthy competition between students and promoting teamwork skills (Naumovska et al., 2023). Science games often present complex challenges that require critical thinking and problem-solving skills, encouraging students to apply scientific knowledge in realistic scenarios (Squire, 2006). Game-based learning also promotes deep learning. Thus, games provide context-rich environments that connect scientific concepts to real-world applications, promoting meaningful learning experiences (Barab et al., 2007). They can help students develop a conceptual understanding of scientific ideas by providing multiple representations, simulations and models (Klopfer et al., 2009).

Immersive puzzle-solving experiences known as "escape rooms" have gained popularity in various domains, including education. In recent years, educators have recognised the potential of escape rooms as a powerful tool to foster engagement and enhance learning outcomes, particularly in science education (Dietrich, 2018; Lathwesen & Belova, 2021; Marin et al., 2021; Stojanovska et al., 2020b; Veldekamp et al., 2021). By combining elements of problem-solving, teamwork and critical thinking, escape rooms provide an interactive and experiential learning environment that captivates students' interest and promotes a deeper understanding of scientific concepts. Consequently, the utilisation of escape rooms as a teaching method aligns well with the objectives of the national science curricula in Macedonia (Stojanovska et al., 2020a), offering an immersive and interactive learning experience that stimulates student engagement and facilitates a deeper comprehension of scientific principles. The escape room approach involves designing a physical or digital "escape room" scenario, whereby students must work together to solve a series of puzzles and challenges related to science concepts in order to "escape" within a given time limit.

Escape rooms offer an exciting and immersive experience that captures students' attention and motivates them to actively participate in the learning process. The element of challenge and the time constraint associated with escape rooms create a sense of urgency, driving students to collaborate, think critically and apply their scientific knowledge to solve complex problems (Dichev & Dicheva, 2017). The captivating nature of escape rooms fosters high levels of engagement and promotes a positive learning atmosphere, as students become highly motivated to succeed and achieve their goals. Escape rooms encourage collaboration and teamwork, fostering the development of essential communication and interpersonal skills. Students must effectively communicate, share information and delegate tasks within their team to decipher clues and solve puzzles. Escape rooms require students to think critically, analyse information and apply scientific knowledge to overcome challenges. This approach encourages students to think creatively, collaborate and develop strategies to find solutions within the given constraints.

By employing questionnaires as a data collection tool, the present research aims to understand the potential influence of the escape room experience on students' self-concept towards science, interest in the subject, motivation and career aspirations in STEM, as well as their situational interest in different non-formal settings. The evaluation framework in the project "Diversity in Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity" (DiSSI) aimed to capture students' *self-concept towards science*, which refers to their perception of their own abilities, competence and identity in the context of science learning (Marsh, 1990). This aspect is crucial, as it can influence students' engagement in science education. *Motivation* is another important factor that was evaluated. Students' motivation reflects their drive and enthusiasm towards learning science. It plays a significant role in their willingness to invest effort and persist in science-related activities (Eccles & Wigfield, 2002). The questionnaire used in the present study also measured students' *interest* in the subject of science. Interest refers to a positive affective response and curiosity that individuals experience towards a particular academic domain or topic. It involves a personal attraction and desire to engage with the subject matter, often leading to increased attention, long-term motivation and exploration of related content (Hidi & Renninger, 2006). The project was also aimed at gathering data on students' *career aspirations in STEM* (science, technology, engineering and mathematics). Assessing students' career aspirations provides insight into their long-term goals and aspirations in STEM fields, which can be influenced by their experiences and exposure to science education (Archer et al., 2010).

Utilising escape rooms as a teaching tool introduces students to an entirely new learning environment, distinct from traditional classroom settings. This shift in scenery prompted us to analyse situational interest, which refers to a temporary state reflecting how an activity impacts an individual, rather than their inherent preference for the activity (Hidi & Anderson, 1992). Five dimensions have been identified as influencing situational interest: novelty, challenge, attention demand, exploration intention and instant enjoyment, with instant enjoyment shown to have the most significant impact (Chen et al., 2001). Situational interest is crucial because the immediate appeal of an activity should translate into both short-term and long-term motivational effects on the learner (Renninger et al., 1992).

Additionally, the study seeks to evaluate the effectiveness of the implemented activities specifically designed around the topic of ecology during the escape room workshops.

Method

Participants

A total of 190 participants completed the questionnaire: 126 students from primary school (12–14 years old) and 64 from secondary school (15–18 years old). Detailed demographic data, including the breakdown of gender and ethnicity, are provided in Table 1.

Table 1
Participant demographic information

Grade level	Primary school	126
	Secondary school	64
Gender	Male	48
	Female	141
Language of instruction	Macedonian	125
	Albanian	53
	Turkish	12

Due to the Covid-19 pandemic, the data collection for the study required researchers to travel to schools located in various parts of Macedonia (the administration of the questionnaires was conducted during May and June 2022). A purposive sampling approach was employed to ensure a diverse sample, including both urban and rural schools, encompassing students from different ethnic backgrounds. By implementing this sampling strategy, the researchers aimed to gather comprehensive data that represents a wide range of students and educational settings, despite the challenges posed by the pandemic.

Instruments

The evaluation framework utilised questionnaires to gather data on students' self-concept towards science and interest in the subject (OECD, 2009), motivation (Ryan & Deci, 2000) and career aspirations in STEM (Kier et. al, 2014), as four subcategories that the project participants were interested in exploring. After the workshops, questionnaire data about the success of the workshops were collected, focusing on the situational interest in the different non-formal settings (Chen et al., 2001) and the effectiveness of the implemented activities (Bartlett & Anderson, 2019; Dugnol-Menéndez et al., 2021; Gordillo et al., 2020; Karageorgiou et al., 2020). These measures aimed to assess the effects of the tools and interventions employed in the project activities and provide valuable insights into the impact on target groups.

Prior to administering the questionnaires, the participants were provided with detailed information about the study and its voluntary nature. Consent was obtained from all of the participants, ensuring their willingness to participate. Furthermore, the participants were informed about the potential use of photographs for research purposes, thus promoting transparency and ethical considerations throughout the study. In the present paper, the pre- and post-questionnaires for students on the topic of ecology are analysed.

Research design

In this study, the escape room was designed as an engaging and interactive face-to-face activity, whereby students from primary and secondary schools from all over Macedonia participated in teams comprising 3–6 members. This group-work setting allowed for collaboration and teamwork among the participants, fostering a dynamic and cooperative learning environment. By conducting the escape room experience in person, students had the opportunity to interact directly with their teammates, share ideas and collectively work towards solving the puzzles and challenges presented to them. This format not only promoted social interaction, but also facilitated the development of important skills such as communication, problem-solving and critical thinking. The inclusion of primary and secondary school students ensured a diverse participant pool, encompassing different age groups and educational and ethnic backgrounds. This diversity brought unique perspectives and experiences to the escape room activity, contributing to a rich learning environment and encouraging peer-to-peer learning and support. The escape room workshops were conducted in various locations, including the university, schools and a botanical garden. The selection of locations aimed to provide diverse and engaging settings for the escape room experience, enhancing the immersion and authenticity of the activity.

The face-to-face nature of the escape room experience also allowed for real-time feedback and guidance from the instructor or facilitator. The instructor played a pivotal role in coordinating the workshops, providing the necessary instructions and overseeing the progress of the teams. This direct interaction with the instructor further enhanced the learning experience and provided an opportunity for personalised support when needed. To form the groups, the instructor randomly selected participants by using coloured strips. This approach not only facilitated random group allocation, but also promoted *collaboration* and *communication* between the students, which are considered essential skills for their future endeavours.

The instructor set a time limit of one hour for the game itself, while the overall workshop duration was two hours. The workshop commenced with an intriguing story that captivated the students' interest, such as finding a cure for an illness or saving the school. Following the story, the instructor explained the concept of the escape room and provided the rules of the game. The puzzles within the escape room did not follow a linear structure, allowing the teams to solve them in any order. There was a total of five puzzles, each designed to challenge the students' critical thinking and problem-solving abilities (Stojanovska et al., 2022). The puzzles used in the escape room were printed on coloured paper and laminated, thus allowing students to write directly on them and making them reusable for subsequent workshops. The puzzles were placed in envelopes and strategically hidden within the classroom or somewhere in the botanical garden, creating an environment of mystery and exploration. During the escape room activity, the students worked collaboratively within their groups to solve all of the puzzles and successfully complete the game. In order to promote independent thinking and problem-solving, no additional literature or access to mobile phones was allowed for seeking answers. All of the necessary materials for puzzle-solving were provided to each group. After successfully solving all of the puzzles, each group opened locks and discovered several pieces of a jigsaw puzzle in a box. All of the groups were then required to collaborate and combine their puzzle pieces to reveal the final prize. In this way, the activity emphasised the importance of collaboration over competition and reinforced the value of teamwork.

The design and development of the educational escape room activities was a collaborative effort involving designated individuals from various educational backgrounds. University professors, science teachers, school principals and one advisor from the Bureau of Development of Education all played a significant role in the design process, lending their expertise and advice as part of the project's National Advisory Board. Their involvement ensured that the activities were aligned with educational objectives, pedagogical principles and the specific needs of students in primary and secondary schools. Their valuable insights and recommendations contributed to the refinement and effectiveness of the escape room experiences, ultimately enhancing their educational value and relevance.

Analysis of the data

The data from the pre-questionnaires were analysed by considering all of the items for each scale. Mean, standard deviation and the reliability coefficient Cronbach's alpha, as a measure of internal consistency (Taber, 2018), were calculated. Independent *t*-tests were used to investigate significant differences between the mean scores of males and females, as well as between primary and secondary school students, across the four scales of the pre-questionnaire.

The results obtained from the post-questionnaires were analysed by calculating the percentage frequencies of agreement for each statement from the corresponding categories.

Results and discussion

In order to evaluate the impact of the escape room experience, comprehensive questionnaires were administered to all of the participants both before and after the workshop. The questionnaires primarily consisted of Likert-type statements, whereby participants were asked to indicate their level of agreement or disagreement. A scale of 1 to 5 was used, with 1 representing "strongly agree" and 5 representing "strongly disagree." The questionnaires were designed to capture important aspects of students' attitudes and perceptions. They specifically assessed students' self-concept towards science, interest in the subject, motivation and career aspirations in STEM before starting the activity. Moreover, the questionnaires included sections to gather the students' perceptions of the conducted activity. The participants' responses provided valuable insights into their experiences and opinions regarding the educational escape room.

I. Initial assessment and pre-intervention findings

The results were analysed considering all of the items for each scale, and the mean, standard deviation and reliability coefficient Cronbach's alpha as a measure of internal consistency were calculated (Table 2).

Table 2

Means, standard deviations and Cronbach's alpha reliability coefficient for the pre-questionnaire.

Scale	Number of items	Pre-questionnaire		
		M	SD	Cronbach's alpha
Interest in science	5	1.69	.80	.853
Career aspirations in science	7	2.27	1.22	.752
Self-concept towards science	6	1.88	.95	.863
Motivation for learning science	10	2.18	1.14	.766
Total	28	2.05	1.09	.895

Table 2 shows the Cronbach's alpha coefficient, indicating the internal consistency of the four scales utilised in the study. The results indicate acceptable internal consistency, with Cronbach's alpha values ranging from 0.752 to 0.863 for the individual scales and 0.895 for the overall pre-questionnaire. These findings align with the cutoff criteria established by Cohen (2000), suggesting acceptable internal consistency across all four scales. It is worth noting that similar studies in the literature (Korkmaz & Erdoğmuş, 2020; Taber, 2018; Zakariya, 2022) have also reported high values for the Cronbach's alpha reliability coefficient, further supporting the reliability of the measures employed in this research.

An analysis to compare the mean scores of females and males on the four scales of the pre-questionnaire was conducted. Independent t-tests were employed to examine whether there was a significant difference between the mean scores of males and females. The results of these tests can be found in Table 3.

Table 3

Comparison of male and female mean scores on the four scales for the pre-questionnaire.

Scale	Groups	M	SD	*t*	*p*
Interest in science	f	1.72	.80	1.812	.070
	m	1.61	.80		
Career aspirations in science	f	2.22	1.21	−.457	.648
	m	2.25	1.19		
Self-concept towards science	f	1.91	.92	1.280	.201
	m	1.82	1.04		
Motivation for learning science	f	2.19	1.14	.517	.605
	m	2.16	1.12		
Total	f	2.06	1.08	1.339	.180
	m	2.01	1.09		

Table 3 presents the mean scores, standard deviations (SD), t-values and p-values for the comparison of females (f) and males (m) on the four scales of interest: Interest in science, Career aspirations in science, Self-concept towards science, and Motivation for learning science. The total column provides the overall mean score for each group. Overall, the results of the independent t-tests indicate that there were no significant differences in the mean scores between females and males across the four scales and the total score. In contrast to the results of Lee et al. (2018) and Siregar et al. (2023), where male students scored higher, as well as the findings of Luttenberger et al. (2019) and Sellami et al. (2023) stating that females outperform males in terms of their self-concept and motivation, our data suggest that gender did not have a significant impact on these aspects of science education.

Furthermore, a comparison was made between the mean scores of primary (p) and secondary (s) school students on the four scales of the pre-questionnaire. Independent t-tests were conducted to assess whether there were significant differences between the mean scores of primary and secondary students. The results of these analyses can be found in Table 4.

Table 4

Comparison of mean scores of secondary and primary school students' mean scores in the four scales for the pre-questionnaire.

Scale	Groups	M	SD	*t*	*p*
Interest in science	s	1.87	.90	4.931	.000
	p	1.60	.73		
Career aspirations in science	s	2.23	1.19	−.991	.322
	p	2.30	1.24		
Self-concept towards science	s	2.01	1.03	3.097	.002
	p	1.82	0.91		
Motivation for learning science	s	2.44	1.21	7.264	.000
	p	2.05	1.08		
Total	s	2.19	1.14	6.706	.000
	p	1.98	1.06		

The results indicate significant differences between secondary and primary students in their scores for interest in science, self-concept towards science and motivation for learning science, as well as for their total scores. However, no significant difference was found between the two groups in career aspirations in science. These findings suggest that secondary students exhibit higher levels of interest, self-concept, motivation and overall scores in science compared to primary students. The observed differences in the results could be attributed to several factors. Firstly, the secondary students surveyed may have had more exposure to science-related topics and concepts, leading to a greater interest in and self-concept towards the subject. They may also have received more specialised instruction and guidance in science, which could contribute to higher motivation levels.

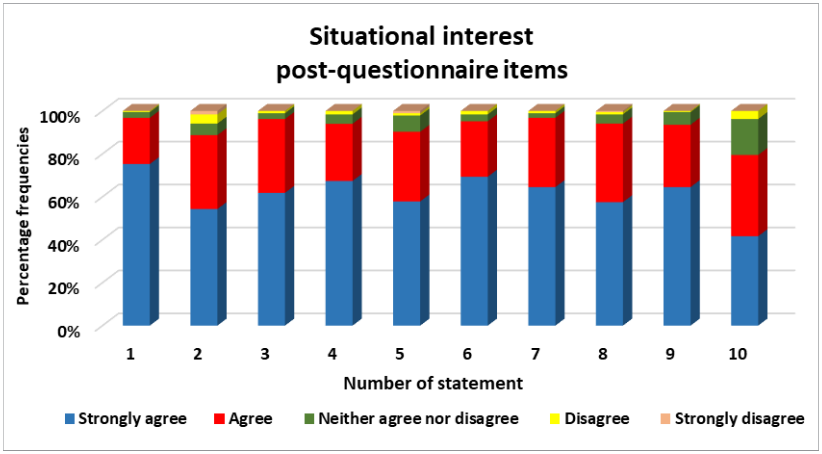
II. Post-intervention outcomes and questionnaire results

The results of the post-questionnaire are presented in six diagrams (Figure 1–6) based on the percentage frequencies.

Ten items from the post-questionnaire focused on assessing situational interest, which can be considered as a construct associated with five dimensions: novelty, challenge, attention demand, exploration intention and instant enjoyment (Chen et al., 1999; Chen et al., 2001). Figure 1 shows that more than 50% of the participants strongly agreed with all of the statements, indicating that they found the workshop interesting and were able to maintain their focus and attention. For this group of statements, the mean value is 1.45. This suggests that the activities presented in the workshop successfully fostered a high level of situational interest among the participants.

Figure 1

Results from the analysis of the situational interest post-questionnaire items.

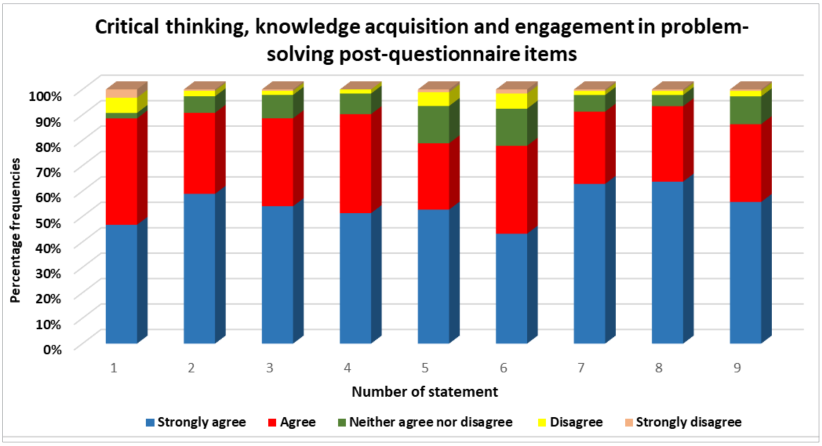


Statements: 1. The lesson in today's workshop was interesting. 2. Dealing with the subject matter was challenging today. 3. I was focused on this activity. 4. I enjoyed today's activity. 5. Today I understood well what we learned in the workshop. 6. Today's workshop was fun for me. 7. There was a lot going on at today's workshop, it was varied. 8. I was attentive in today's workshop, from the beginning to the end. 9. Today's material at the workshop attracted me, so I participated. 10. I want to delve into the details of the material we discussed at today's workshop.

The second section of the post-questionnaire was designed to assess the effectiveness of the implemented activities and examine the impact of the methods and tools utilised within the group. These findings are presented in five sets of statements (Figures 2–6). Specifically, the results from Figure 2 indicate a high mean value of 1.58 for the statements evaluating the promotion of critical thinking, knowledge acquisition and engagement in problem-solving. Analysis of the students' perceptions revealed that they were encouraged to approach the material differently and review the concepts related to the topic. Furthermore, approximately 80% of the participants expressed (agreed or strongly agreed with statement 5) that they felt they learned better through the game-based approach compared to a traditional lecture format.

Figure 2

Results from the analysis of the post-questionnaire items promoting critical thinking, knowledge acquisition and engagement in problem-solving.

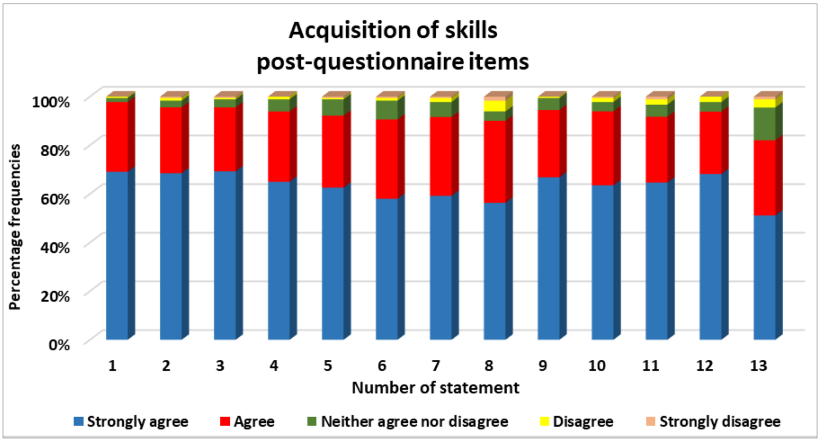


Statements: 1. I was learning while playing. 2. The escape room activity encouraged me to think about the material in a different way. 3. The escape room activity was an effective way to review the concepts of this theme. 4. The escape room activity was an effective way to learn new information related to this theme. 5. I learn better through a game than through a classic lecture. 6. I wanted to explore all aspects of the game, even if there were false directions. 7. The game had a clear purpose. 8. There were different types of puzzles. 9. There were puzzles that made me think "outside the box".

The third set of items analysed the degree of acquiring and improving skills through the escape room method that students believed they achieved (Figure 3). From Figure 3 it can be seen that the participants acquired skills for problem-solving, decision-making and logical reasoning, as well as improving their communication abilities, collaboration and teamwork. The results show a high mean value of 1.38. Similar results were obtained in a study on the use of escape room activities in occupational therapy courses, in which students believed they had developed curricular skills with a mean value between 3.84–4.28 on a scale where 5 is "strongly agree" (Dugnol-Menéndez et al., 2021). The participants in the latter study felt that they had strong organisational skills while performing the activities and effectively developed strategies within their groups, thereby enhancing their ability to manage time efficiently. Additionally, they exhibited persistence in completing the activity and demonstrated a high level of adaptability to new situations.

Figure 3

Results from the analysis of the post-questionnaire items promoting acquisition of skills.

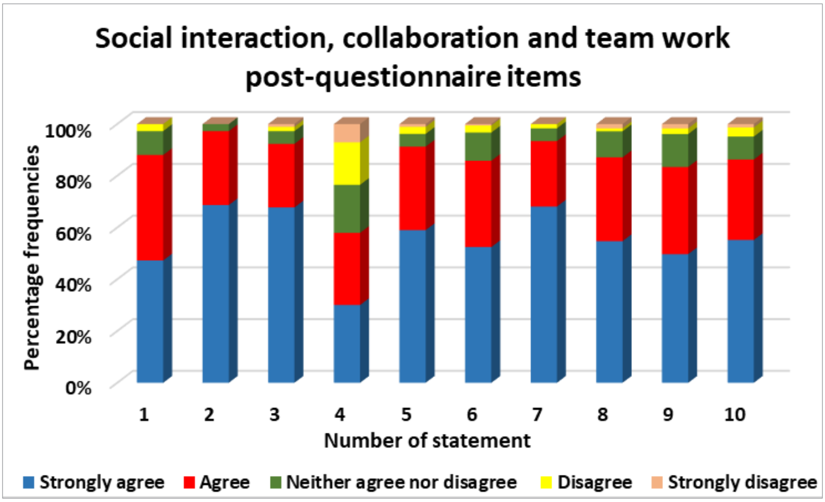


Statements: 1. Communication. 2. Teamwork and collaboration. 3. Problem-solving. 4. Decision-making. 5. Adapting to new situations. 6. Planning and time management. 7. Analyse and synthesise. 8. Critical thinking. 9. Logical reasoning. 10. Creativity. 11. Organisation. 12. Persistence. 13. Autonomous learning.

The effects of the game activities on social interaction were analysed in greater detail through a set of items presented in the fourth diagram (Figure 4). The results indicate that the activities facilitated collaboration and the sharing of knowledge among participants, fostering a friendly environment and increasing confidence levels within the group. The mean value for this set of statements was 1.59. Similar high scores for students' perception of shared knowledge have been observed in other studies (Bartlett & Anderson, 2019). Furthermore, in educational escape rooms designed for teaching software modelling, students reported a high level of involvement from team members (Gordillo et al., 2020).

Figure 4

Results from the analysis of the post-questionnaire items promoting social interaction, collaboration and teamwork.

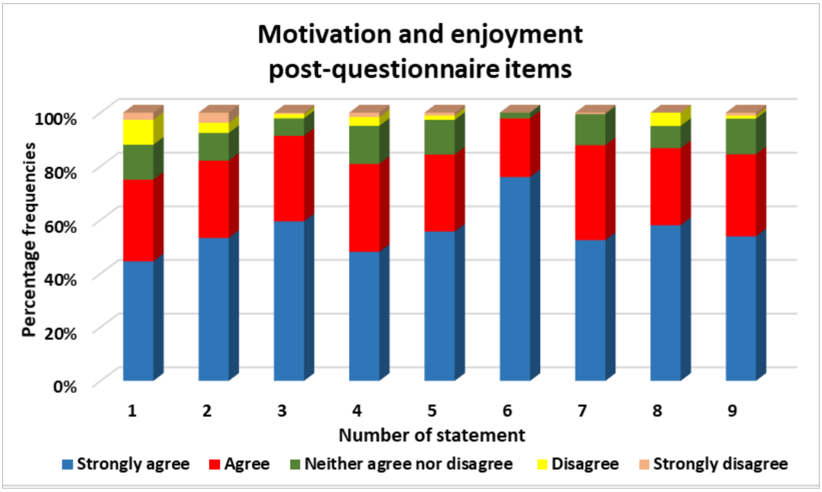


Statements: 1. I was able to learn from my peers during the escape room activity. 2. I was able to learn something new on this theme through discussion with classmates from the group. 3. I felt like a part of the team. 4. I prefer to participate in escape room activities as part of a team. 5. I would like to get more help while solving the puzzles. 6. All team members were almost equally involved in solving the puzzles. 7. The abilities of the team and the difficulty of the puzzles were at about the same level. 8. Throughout the game I cooperated and communicated with all of the team members. 9. After the game, I had a better understanding of what cooperation means. 10. After the game, I gained more confidence in my peers.

Figure 5 presents the results obtained for a set of statements related to motivation in the game activities. The mean values for individual statements range from 1.22 to 1.71, indicating a generally high level of agreement with the statements. The participants reported being engaged in completing or winning the game and becoming motivated to learn. They also expressed a sense of excitement and enjoyment, feeling immersed in the game's story and finding the game to be fun. Additionally, solving puzzles in the game increased participants' confidence and provided an unforgettable experience. The mean value for the group of statements related to motivation is 1.56, suggesting the game activities had a positive impact on the participants' motivation.

In their study in courses on occupational therapy, Dugnol-Menéndez et al. (2021) reported increased engagement and immersion in the activity when utilising escape room applications. Similarly, a study conducted in a technical high school demonstrated that the confidence of students increased after solving each puzzle in an escape room setting (Karageorgiou et al., 2020). These findings highlight the positive impact of escape rooms in fostering engagement, immersion and confidence among participants in various educational contexts.

Figure 5
Results from the analysis of the post-questionnaire items promoting motivation and enjoyment.

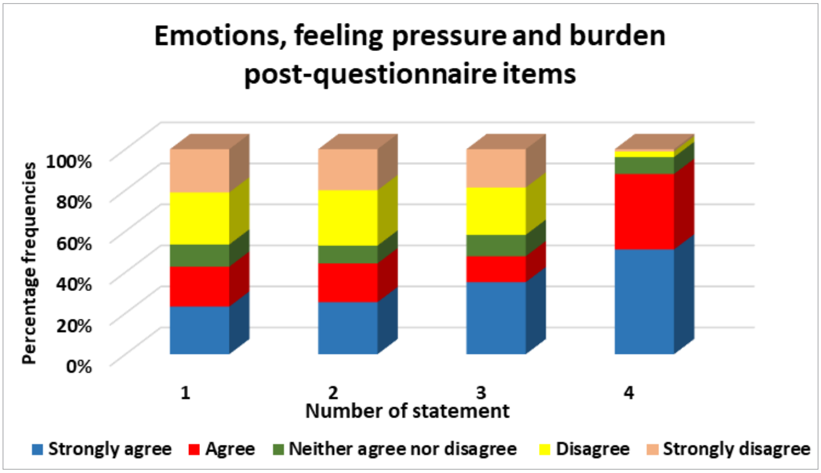


Statements: 1. Games motivate me to learn. 2. While playing I was trying to complete/win the game. 3. I almost didn't notice how quickly the time passed. 4. I was excited while playing. 5. I felt like a part of the game's story. 6. The escape room game was fun for me. 7. My confidence increased after solving each puzzle. 8. The game was an unforgettable experience. 9. After the game I felt more confident.

The next diagram (Figure 6) provides a summary of the results obtained for a set of statements and refers to the created positive or negative emotions, created stress or feeling distracted. The mean scores range from 1.59 to 2.94, indicating varying levels of agreement or disagreement with the statements. The results suggest that while some participants experienced difficulty focusing and perceived certain elements of the escape room activity as distracting, there was a prevailing presence of positive emotions. Other researchers have found similar results with regard to such statements (Bartlett & Anderson, 2019; Karageorgiou et al., 2020).

Figure 6

Results from the analysis of the post-questionnaire items promoting emotions, feeling pressure and burden.



Statements: 1. I found it difficult to focus on the activity/study because I felt stressed or overwhelmed. 2. Some parts of the escape room activity (e.g., codes, puzzles, etc.) distracted me/interfered with my learning. 3. I felt scared/anxious at the beginning of the game. 4. Positive emotions prevailed over negative ones.

It is important to note that a subset of the participants reported feeling scared or anxious. These findings highlight the diverse range of experiences and emotions that individuals may have during an escape room activity, indicating the need for consideration and support in creating an optimal learning environment.

Conclusions

In the DiSSI project, a framework was developed to evaluate the effects of tools on target groups, specifically focusing on students' perceptions of their self-concept towards science, interest in the subject, motivation and career aspirations in STEM. In order to assess these variables, a questionnaire was employed utilising established scales. The study also aimed to understand the influence of the escape room experience on situational interest in non-formal settings and to evaluate the effectiveness of escape room activities and their impact on student engagement and attitudes towards science.

The data presented in the text indicates substantial support for the effectiveness of escape room activities in science education. Specifically, the decision to conduct the escape room as a face-to-face, group work activity with teams consisting of 3–6 participants seems to have ensured an immersive and interactive learning environment that potentially fostered collaboration, communication and critical thinking among students from different ethnic backgrounds.

It is important to note that the sample used in the study was not selected randomly, which may limit the generalisability of the findings. Future research could aim to address this limitation by utilising random sampling methods in order to enhance the generalisability of the findings. Additionally, further investigations could explore the integration of other methods, such as the use of tip cards, to enhance the implementation of educational activities. Further insights may also be gained through the analysis of questionnaires distributed among other target groups and on different topics (such as gases and electrical circuits). It would also be valuable to assess the knowledge gained through the application of escape room methodologies in participating countries outside the project.

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Someone Like Me: A Trial of Context-Responsive Science as a Mechanism to Promote Inclusion

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This paper provides evidence gathered from two suites of non-formal science activities that were intended to increase engagement in science by culturally diverse groups. Both studies involved the delivery of science activities that were designed, implemented and evaluated to show culturally contextualised science. The activities were run in two very different contexts (urban and very rural areas) and were designed to be of relevance to two distinctive cultural groups (those with links to South Asia, and those being educated through the medium of Gaelic, an indigenous minority language in Scotland), while also actively engaging with those beyond the target group. The link between language identity and culture was incorporated into the design of both sets of activities as well as the qualitative evaluation. The latter considers how the participants' assessment of the interventions, implemented by writing or drawing on a blank postcard, was designed to provide unstructured responses and explores what the resulting data revealed about the impact of the interventions. The findings suggest that the set of activities that most strongly engaged participants on the value of diversity in the creation of scientific knowledge, as well as increasing their focus on the consequences of scientific activity, were those that facilitated a more exploratory approach to the subject matter. By contrast, activities that had to be done according to a standard scientific protocol produced growth in subject-specific knowledge. The present paper explores the principles of the inclusive pedagogies that informed the design of the activities and discusses how these were operationalised in two very contrasting cultural contexts. The key finding was that presenting science as social practice, rather than as being socially neutral, is key to promoting engagement, along with the benefits of explicitly demonstrating the relevance of science to participants' daily lives.

Keywords: inclusion, equity, culture, diversity, context-based science

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Nekdo kot jaz: preizkus naravoslovja, prilagojenega kontekstu, kot mehanizem za spodbujanje inkluzije

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V prispevku so predstavljeni dokazi, zbrani na podlagi dveh sklopov neformalnih naravoslovnih dejavnosti, katerih namen je bil povečati vključenost kulturno raznolikih skupin v naravoslovje. Obe študiji sta vključevali izvajanje naravoslovnih dejavnosti, ki so bile zasnovane, izvedene in ovrednotene tako, da so prikazovale naravoslovje, kontekstualizirano s kulturo. Dejavnosti so se izvajale v dveh zelo različnih okoljih (mestna in podeželska območja) in so bile zasnovane tako, da so bile pomembne za dve različni kulturni skupini (člani prve imajo vezi z južno Azijo, člani druge skupine pa se izobražujejo v gelščini, jeziku avtohtone manjšine na Škotskem), hkrati pa so aktivno vključevale tudi osebe zunaj ciljne skupine. Povezava med jezikovno identiteto in kulturo je bila vključena v zasnovo obeh sklopov dejavnosti pa tudi v kvalitativno vrednotenje. Zadnje obravnava, kako so udeleženci ocenjevali intervencije, ki so jih izvajali s pisanjem ali z risanjem na prazno razglednico, in kako so bili zasnovani za zagotavljanje nestrukturiranih odgovorov, ter raziskuje, kaj so pridobljeni podatki razkrili o učinku intervencij. Rezultati kažejo, da je bil sklop dejavnosti, ki je udeležence najmočneje pritegnil k razmišljanju o vrednosti raznolikosti pri ustvarjanju naravoslovnega znanja in povečal njihovo osredinjenost na posledice naravoslovne dejavnosti, tisti, ki je omogočal bolj raziskovalen pristop k predmetu. Nasprotno pa so dejavnosti, ki jih je bilo treba izvajati skladno s standardnim znanstvenim protokolom, povzročile rast znanja o posameznem predmetu. V tem prispevku so raziskana načela inkluzivne pedagogike, ki so bila podlaga za oblikovanje dejavnosti, v prispevku pa obravnavamo tudi, kako so se ta načela izvajala v dveh zelo kontrastnih kulturnih okoljih. Ključna ugotovitev je bila, da je za spodbujanje sodelovanja udeležencev ključnega pomena predstaviti naravoslovje kot družbeno in ne družbeno nevtralno prakso ter da je koristno izrecno prikazati pomen naravoslovja za vsakdanje življenje udeležencev.

Ključne besede: inkluzija; pravičnost; kultura; raznolikost; naravoslovje, ki temelji na kontekstu

Introduction

In Scotland, one of the four nations of the UK and the location of the reported study, the devolved government has had a strong focus on promoting STEM for all pupils. Despite this, concerns persist about recruitment to professional STEM pathways, overshadowing the importance of STEM for citizenship or socialisation (Scottish Government, 2017). The agenda to recruit professional scientists tends to understand science as a neutral and objective study of the natural world, set apart from the cultural environment in which it is practised. Paradoxically, while upholding the cultural neutrality of science, policy drivers may, unintentionally, prevent the equitable distribution of the benefits of STEM learning across the population. The present study considered whether presenting science as an activity intimately connected to its cultural context could enhance the engagement of groups who are currently under-represented in science. The intention was to achieve educational inclusion, as defined in the paper, as well as to meet the stated intention of Scottish education policy that every child should be 'present, participating and succeeding' (Scottish Government, 2019).

At present, there is a sad litany of groups who are under-represented in STEM or, more accurately, minoritised by the culture and practices of STEM (Campaign for Science and Education, 2016). Characteristics associated with disproportionately low uptake in STEM in the post-compulsory phases of education and in the STEM workplace provide the best indicator we currently have for those at risk of disaffection from science more generally. Evidence identifies that those with a below average engagement with STEM include those living in conditions of socioeconomic deprivation, those with disabilities, those whose first language is other than the dominant language of instruction, LGBTQ+ people, young carers, and those in remote geographical areas, as well as with intersecting combinations of such characteristics (All-Party Parliamentary Group, 2020). Other characteristics result in a more nuanced picture of exclusion, giving variable outcomes for people of colour depending on the precise ethnic identity, while gender is disadvantageous in different ways across different STEM disciplines (Campaign for Science and Education, 2016).One factor that recurs through studies of why these disparate groups are alienated from science and other STEM subjects is the discrepancy between their personal cultural identity and that which they associate with the pursuit of science (Archer et al., 2020; Asbacher et al., 2010; Vincent-Ruz & Schunn, 2018). The study that is reported here considers two interventions that sought to actively include participants who are culturally diverse: one case linked to ethnicity and the other to linguistic heterogeneity.

Inclusive education as aspiration and practice

Inclusion is commonly viewed in the UK as an approach to education that seeks to address the educational needs of children with disabilities within existing educational structures. This 'shorthand' view of diversity and inclusion may well arise from the fact that children with disabilities were legally excluded from standard state educational provision and educated in segregated settings (or not at all, in some cases) until well into the twentieth century in both Scotland and the rest of the UK. While disability may have been a proving ground for teachers' notions of differences and otherness, the list of characteristics set out in the introduction reminds us that difference takes many forms. Initially, as further diversity characteristics were understood to be associated with differing educational achievement, different pedagogical strategies were devised for the different categories of difference. The Swan Report (Committee of Enquiry into the Education of Children from Ethnic Minority Groups, 1985), for instance, was a response to the scholastic under-achievement of children of colour whose parents had arrived in the UK after World War Two. However, rather than a raft of different forms of inclusion, growing awareness of the complexities of educational identity has resulted in a more holistic notion of inclusion, as expressed in UNICEF's (n.d.) definition:

> Inclusive education allows students of all backgrounds to learn and grow side by side, to the benefit of all.

Accompanying this, a newer notion of inclusion has seen a shift away from deficit thinking about diversity towards asset-based practices and consideration of how we can make a shared learning environment conducive to optimal learning by all. Success with such an approach has previously been reported in careers guidance (Drobnič, 2023) and might be expected to have a comparable impact in orientating young people towards science. The transformation has wrought a reconsideration of how diversity can enrich learning, rather than presenting a barrier to curriculum delivery (Göransson & Nilholm, 2014). However, the reality in the UK differs markedly from this aspiration. In many places, provision is very granular, with different school types serving young people with different characteristics. Even in Scotland, where education in the neighbourhood school is the presumed option (Scottish Government web site), STEM subjects are not equally taken up, despite being universally available. This raises questions about the ways in which STEM is especially exclusionary. The answer may lie deep within the culture of STEM, much of which springs from historical legacies that are no longer visible but have conferred an enduring pattern of thinking, practices and values regarding STEM subjects. To render science education genuinely inclusive, current practices and assumptions need to be subject to critical scrutiny in such a way as to dismantle the barriers that are embedded within them. This includes the remoteness of science from everyday practices in the home and community, the paucity of diverse role models, the use of unfamiliar terms and apparatus, and the notion that only controlled experimentation can produce valid findings (Essex, 2023). The repositioning of science as social knowledge could, conversely, be expected to enhance its accessibility to learners from a wide range of cultures.

Cultural diversity in science

Science could justifiably be described as having its own distinctive culture if we adopt a sociological definition of culture. This describes culture as being the values, beliefs, practices, language and communication that people share as a result of learning. It also includes the artefacts associated with their shared ways of thinking (Hall et al., 2003). Science clearly meets this definition in that it shares beliefs, some of which are foundational, including the belief that natural phenomena are subject to verifiable physical laws. Scientists also generally share the belief that ideas should be verifiable by controlled experimentation, and they communicate their work using a shared technical vocabulary, formulae and diagrams. Their artefacts are the very similar scientific instruments they use to conduct their experiments. Furthermore, treating science as a culture has enabled researchers to explore how it confers 'capital' in the Bourdieusian sense, that is, the power to make choices and achieve self-advancement (Archer et al., 2020) in the way that Bourdieu described 'cultural capital' operating in wider society.

The agency that capital confers on its possessor is not, however, of universal value, but is dependent on the cultural environment in which the possessor finds themselves. This is the mechanism by which children who have had prior exposure to culture that is considered desirable at school find that they already have knowledge that is favoured in the school environment. Bourdieu considered this to be the mechanism whereby school sustains existing class inequalities (Bourdieu, 1984). The same mechanism is applicable when the impact of science capital is analysed. Children who come from home lives where science is used, talked about and valued, those who engage in scientific activities during their leisure time, are found to do well in science and to choose to pursue it after it ceases to be a compulsory school subject (Archer et al., 2020). One of the key recommendations to arise from Archer et al.'s work is that teachers need to portray science not as something separate from pupils' everyday life, but as something relevant to it. Such endeavours could be interpreted as a renewed attempt to bridge 'two cultures' (Snow, 1959). As Reingold and Zamir (2017) note, despite the pressing need for such cultural mediation, there is far more said in policy than is known about successful practical implementation.

The need for conscious mediation between the culture of science and the 'popular' cultures of pupils' everyday lives is important for its uptake. School science has a history as an elitist subject, available only to people attending schools that were selective based on academic attainment and, very frequently, based on coming from a family that could pay large fees for school attendance (Jenkins, 1979). The fees enabled the provision of specialist laboratory facilities for science and the recruitment of highly educated teachers, who presented a curriculum that was abstract and very intellectually demanding. The same teachers were over-represented in organisations that have come to define what science education ought to be (Jenkins, 2013), such as the Association for Science Education. Ultimately, an elite minority have made their own, very particular version of science synonymous with the entire subject. Their legacy is a subject that is commonly perceived as 'hard' and 'male, pale and stale' (Chambers, 1983; Finson et al., 1995), and that has not responded in a timely manner to the ever more diverse nature of learners in science classrooms (All-Party Parliamentary Group, 2020). 'Draw-a-scientist' methodologies show repeatedly that young people see scientists as someone not like them, in that they are older, only one gender and only one ethnicity. They are also commonly depicted as 'mad', secretive, engaging in dangerous activities and exceptionally clever (Chambers 1983; Finson et al., 1995). Other researchers describe the frequency with which scientists are perceived as different, often cleverer than them (Osborne et al., 2010). Children's notions of scientists as people very different from themselves are accompanied by ideas about the strangeness of what they do, how they do it and the objects they use. This contrasts sharply with 'folk science' or 'naïve science', which relates to familiar, everyday objects and phenomena (Champagne et al., 1983). The combination of these factors makes formal science seem culturally alien to many young people.

Inclusive science pedagogy

Attempts to enact inclusion in pedagogy quicky become mired in conflicting performativity pressures to which science, as a 'gatekeeper' subject, is especially prone. Such efforts are also hampered by the tendency of school systems to view diversity as an administrative challenge and a drain on resources

(Essex et al., 2019). The fear of diminishing attainment by promoting inclusion is a common fallacy, despite evidence to the contrary (Palid et al., 2023). The common result is a tokenistic reference to different cultures, which may succeed only in 'othering' minority groups (Alexiadou & Essex, 2015). Gibson (2015, p. 2) notes that this leads to a situation in which "[i]nclusion becomes about attempts to induct that which is 'different' into already established forms and dominant institutional cultures". However, full inclusion would seek not to subsume a minority culture into the hegemonic culture, but to actively incorporate diverse positions as valuable assets for everyone.

Mensah and Larson (2017) posit six approaches to (culturally) inclusive pedagogy. They call for culturally relevant, culturally responsive, culturally congruent and culturally sustaining science education for both teachers and students. They also advocate the intentional deployment of the 'funds of knowledge' that students bring in from beyond the classroom and, aligned to this, they encourage the use of the 'third space', that is, places that are neither school nor home, for the elicitation of such knowledge. These approaches all affirm cultural identities and draw upon them in the creation of scientific knowledge, emphatically rejecting any notions of inadequacy amongst the marginalised. Similarly, Cobian et al. (2024) advocate the centring of cultural identity in STEM undergraduate programmes. Evidence of the practical difficulties in implementing these changes in practice is provided by Underwood and Mensah (2018), whose interviews with science teacher educators indicate a recognition of the imperative to enact culturally responsive pedagogies, but, at the same time, reveal a lack of knowledge of how this might be carried out in practice. The strategies are intended to show science education to be much more than the transmission of objective facts and to include the development of critical insights into how science has been practised and used. However, Cobian et al. (2024) caution that systematic changes in the support and climate in educational spaces are needed alongside curriculum and pedagogic reform if uptake is to be diversified. One under-acknowledged source of support for minoritised students who persevere with science is their community, and initiatives that enable community members to contribute to teaching are a powerful source of affirmation (Aschbacher et al., 2010).

The characteristics of inclusive pedagogy can be summarised in the following framework, based on work by Pomeroy (1994) and updated in the light of evidence that has been published since its inception (Essex, 2023). Note that this framework is designed to ensure optimal learning by all pupils, irrespective of individual characteristics, but it is certainly applicable to culturally diversity populations.

1. Relevant

The importance of showing science as something that impacts upon learners' daily lives has been established by various context-based science courses. Although the academic gains are commonly not large, there are marked improvements in attitudes towards science and there is evidence of a reduction in the gap between groups in this regard by enhancing the positive views of the group that had been previously less enthusiastic about science (Bennett et al., 2007). It is important, however, that the contexts and applications of science are shown in a diverse way, so that a 'male, stale and pale' image of people to whom science matters is not perpetuated. Another aspect of making science relevant is the deployment of multi-modal resources, including hands-on and sensory exploration, different types of images, speech, written texts and a range of digital media. A further pedagogic consideration is the deployment of a range of teaching and learning strategies, including group work. This enables pupils to draw on their personal knowledge and to have it validated.

2. Free from prejudice and respectful of diverse responses

Inclusive pedagogy must, of necessity, start from the position that everyone has both the capacity to learn and the capacity to contribute. This requires teachers to challenge any barriers created by low expectations and negative stereotyping. In this environment, diversity is seen as a resource to be valued, rather than a problem to be corrected (Rapp & Corral-Granados, 2021). Critically challenging structural barriers to the fair treatment of everyone is an important aspect of actively countering prejudice. By showing how inequalities in power have enabled science to become a exclusionary undertaking, we equip our young people to re-evaluate their ideas about what science is and who has made valuable but unacknowledged contributions.

3. The three R's: reflective, reflexive and responsive

Teacher disposition is at the heart of inclusive teaching, although many teachers continue to see inclusion as a question of resourcing or the acquisition of specialist techniques (Alexiadou & Essex, 2015). The tendency to locate difficulties associated with inclusion in the diverse pupil perpetuates a deficiency model of diversity. The most effective teachers have been found to be those who take responsibility for the learning in their classrooms and demonstrate reflexion, that is, they recognise their role in the events that unfold. They incorporate this awareness of their own impact in an ongoing cycle of observation of pupils during lessons, reflection on the outcomes of lessons and, in response to the insights derived from this, revise future teaching as indicated (European Agency for Development in Special Needs Education, 2012).

4. Constructed to offer diverse pathways to success

One of the fundamental pedagogic shifts that has taken place in response to the increasingly diverse pupil population is the shift away from a single learning pathway that all pupils will follow in an identical manner. It is now expected that there will be multiple ways to undertake an expected piece of learning, providing challenge alongside support, as needed. Support may be required with language, whether this is because pupils customarily use other languages than the one of school instruction, or whether it is due to unfamiliarity with technical vocabulary and unfamiliar apparatus. Ensuring that all learners can both understand and contribute to the learning constitutes testimonial epistemic justice (Fricker, 2007), which must be a primary aim of inclusive education. Another crucial consideration is the need to allow sufficient time for the repetition and reflection that give rise to deep learning (Bruner, 1966). In the case of science, which is commonly presented as a content-rich subject (Hirsch, 1996) that requires children to learn facts, emphasising science as an approach may be a helpful way to reconceptualise success. This provides the learner with the chance to tackle problems in a scientific manner and removes anxiety about knowing the right answer.

Research aims

The present study was constructed to evaluate the impact of intentionally culturally inclusive science activities on young people's responses to such activities. The work was designed to answer the following research questions:

1. To what extent do intentionally inclusive science activities successfully convey the intended scientific concepts?
2. Do intentionally inclusive science activities alter young people's ideas about science?

Method

Participants

Three plant science activities were run in two Scottish botanic gardens and at two science festivals, where participants included families and social groups as well as school groups of pupils and their teachers. The venues were selected because of their location and because the places where the activities were being conducted could reasonably be expected to attract culturally diverse visitors. The sampling was random, as it depended on the decision of adults to visit the gardens or festivals. The participants chose how long they wished to spend on the activities and the time spent varied from a few minutes to half an hour.

The second set of activities comprised forensic science tests devised to appeal to schools educating children through the medium of Gaelic, the majority of which are based in the rural northwest of Scotland and islands to the west of that. Gaelic is commonly presented in popular media as a language linked to a historic past, but not as a modern language of the twenty-first century (Dumore, 2017). For this reason, the research team was interested to know whether that stereotype could be challenged by the presentation of modern analytical techniques and materials in the medium of Gaelic. Sampling was purposive, in that all of the schools in the target area were contacted. However, access to the young people was by the agreement of the teachers in the schools.

Instruments

The evaluation process was approved by the University of Strathclyde's School of Education Ethics Committee before data gathering began. In order to be as inclusive as possible, designing evaluation tools that were equally inclusive was integral to the design of the activities. The same format of data gathering instrument was used in both sets of activities, with appropriate minor modifications to make it relevant to the set of activities to which it related. To that end, postcards were used that asked the young people who took part in the interventions to write or draw their ideas about plant science or forensic science before doing the activities, and then again afterwards (Ross et al., 2023; Ross, 2023). The question at the top of the postcard was 'What do you think about when you hear the words plant science/forensic science?'. On the back of the postcard, to be filled in after doing the activities, was the question, 'What do you <u>now</u> think about when you hear the word plant science (or forensic science)?' The postcards were available in English and the sixteen community languages in use in Scotland: Arabic, French, Finnish, Gaelic, German, Greek, Italian, Malay, Maltese, Polish, Romanian, Russian, Urdu, Pashto, Sinhalese and Welsh. Translations into all of these languages had been obtained by asking members of a public engagement group who knew languages other than English, and participants could choose to use whichever version of the evaluation card they wanted. Skin-tone crayons were provided to enable participants to represent people of diverse ethnicities in their drawings. In addition, a ten-item questionnaire was created on a secure web area and a QR code to access this was shared with participating adult members of the public and teachers accompanying the young people, based on the Dimensions of Attitudes towards Science survey instrument (Wendt & Rockinson-Szapkiw, 2018). Finally, field notes were written at the end of each session and noteworthy comments made by the participants were recorded in the notes.

The questionnaire administered to teachers and accompanying adults at both sets of activities contained the following questions and statements:

Q1 I think that science education is essential for helping children and young people become more involved with society's problems.

Q2 I enjoy teaching science

Q3 Which subjects do you think that your children and young people like best?

Q4 In what ways or contexts do you think they recognise the importance of science in their daily lives?

Q5 What jobs do you think your children and young people aspire to do?

Q6 How many people do your children and young people know who use science in their job? Who are they and what jobs do they do?

Q7 Do your children and young people find science interesting?

Q8 Do your children and young people find science hard?

Q9 Do you think that the sort of science you teach in school/youth group is the same as what real scientists do?

Q10 Do your children and young people think they could make a new scientific discovery?

Science activities

Two sets of science activities were devised, informed by the principles of inclusive pedagogy, especially those of Menson and Larson (2017). The activities were intended to model culturally responsive approaches relevant to two cultural groups who appear to be under-represented in the media of science education, and who may therefore feel alienated from science.

The first set of activities related to the interconnections between Scottish plant scientists and those of South Asia, with the intention of engaging people who had links to, or were interested in, South Asia. The activities were informed by ideas of 'decolonising the curriculum' and considering the power imbalances that made it possible for northern hemisphere travellers to exploit the people and natural resources of the southern hemisphere, including its plants (Begum & Saini, 2019). Most importantly, however, there was no suggestion that the activities were only for those of South Asian heritage. This suite contained three activities:

1. A sniff and match activity, in which visitors were asked to match whole spices to processed spice; for example, matching whole cloves to clove oil by smell. This activity was accompanied by conversations about the parts of the plants that gave us spices, the evolutionary origin of spices and the biological activity as well as chemical composition.
2. A 'junk modelling' activity in which visitors were asked to build a plant carrying case suitable for carrying specimens (a piece of sprouting ginger rhizome, coriander seeds and saffron crocus bulb) on a ship for six months, as the eighteenth-century explorers had to. The activity was accompanied by a discussion about the impact of advances in technology to transport plants on local and global economies and a conversation about the lives of some Scottish and South Asian plant scientists, for whom an accompanying set of short biographies were provided.
3. A cyanotype (blue printing) activity in which visitors were asked to use letters, negative images of plant scientists from Scotland and South Asia, and pressed South Asian plant specimens to create an image showing what they had learned.

The second suite of four activities comprised a set of forensic activities designed to enable participants to deduce who had dumped litter, resulting in the death of a rare seabird that had ingested the litter. The context was chosen to be of relevance to children in places where ecotourism involving observing wildlife is essential to the local economy. The associated worksheets, casts of shoe prints, photographs of evidence, labels on experimental apparatus and reagents used by the pupils were written in Gaelic and a supporting vocabulary list was provided for teachers with Gaelic-English translations of all of the technical terms to assist its use with pupils who were not proficient Gaelic speakers. The context of the analysis concerned a puffin that had been found dead, with the death being attributable to the bird having eaten plastic items among litter that had been illegally dumped on a beach. The importance of ecotourism in rural parts of Scotland was intended to make the problem relevant to the young people.

The evidence that was presented were footprints from the crime scene, fingerprints and a (synthetic) blood sample recovered from items in the bag of rubbish, as well as DNA profiles from blood and hairs found at the crime scene. These were compared to those of three suspects, whose data was provided. The activities followed on sequentially, although they were not all offered to all participants, depending on the ages of the children. The sequential nature of the activities required them to be carried out in an ordered way. This contrasted with the first suite of activities, each of which was 'standalone' and so permitted participants to do the activities in any order they chose or to omit activities completely if they wished to. The forensic science activities were run in schools in the northwest of Scotland, where teachers were able to observe the resources being used with their pupils. The sessions lasted between 40 and 60 minutes. In addition, three professional development sessions were run online for teachers to support them in the use of the forensic kits. Although the activities were different in the second group, basic demographic data captured on the evaluation cards indicated that the age profiles of the participants were similar to those who engaged with the first set of activities.

Research Design

The data processing took the form of a compilation of the quantitative data generated by Likert scales associated with some of the questions and statements in the questionnaire given to teachers and other adults. The answers to the open-ended questions on both the questionnaire and the postcards were subject to thematic analysis in the following stages. Firstly, the two sets of data were coded separately, that is, terms, phrases or images with shared meaning (though not necessarily the same words) were assigned a common code (Braun & Clarke, 2006).

The use of the postcards is illustrated by the following example. One completed postcard depicted the outline of a body on the floor, a microscope and the phrase 'DNA'. The outline of the body and the microscope were judged to be about the scientific process specific to the context of forensic science, while the DNA was judged to be factual knowledge specific to the activity. Afterwards, the same participant provided a bullet point list setting out materials relevant to the activities they had done. The list comprised blood, hair, DNA and fingerprint. Initially reflecting repeatedly upon the very disparate data gave rise to lower order codes, such as forensic science process and forensic science reagents. Further reflection gave rise to three high order themes that overarched all of the meanings conveyed by the raw data, of which the lower order themes formed sub-themes. The themes were general epistemology, topic-specific content and the impact of scientific knowledge. The resultant subthemes and derived themes are shown in the columns headed 'sub-themes' and 'themes' respectively in Table 2.

After analysis of the raw data, the two sets of data were observed to give equivalent sub-themes, which made it possible to compare how they had been received by the participants. Finally, the analysis was compared with field notes and feedback from colleagues who had been present to ensure that the themes fairly represented the reactions of the participants (King, 2004). Once the themes and sub-themes had been agreed, the four data sets (plant science, forensic science; before intervention and after intervention) were analysed separately. A tally was made of the incidence with which the different sub-themes were expressed in the raw data, expressed as a proportion of the total responses, using the formula:

$$\frac{\text{number of responses corresponding to the sub-theme}}{\text{total number of responses}} = \text{proportion of answers referring to the sub-theme}$$

The descriptive statistical approach enabled a comparison to be made of the frequency with which different ideas were expressed before carrying out the activities and identified any shift in thinking due to the intervention.

Results

The data gathered are summarised below.

Table 1
Responses to the questionnaires administered to adults.

Q1 I think that science education is essential for helping children and young people become more involved with society's problems.

Response	Tally
Strongly agree	9
Agree	6
Neutral	
Total	15

Q2 I enjoy teaching science

Response	Tally
Strongly agree	4
Agree	8
Neutral	3

Q3 Which subjects do you think that your children and young people like best?

Subject	Category/number of responses	Number of responses
Practical science	STEM 11	2
Science		4
STEM		3
Mathematics		2
Active learning	Experiential learning 18	4
Practical science		2
PE		5
Art		6
Music		1
Ones that connect to their context	Other 4	1
Health and well-being		1
Reading/literacy		2
Total		**33**

Q4 In what ways or contexts do you think they recognise the importance of science in their daily lives?

Response	Location	Number
Few or none	Not applicable	**4**
Teaching/class discussion	School input	3
Science teaching		2
Hands on experiences		2
	Total	**8**
News	Out of school experience	1
Technology around them		1
Natural world		1
Climate change		1
Media		1
	Total	**5**
	All responses	**17**

Q5 What jobs do you think your children and young people aspire to do?

Job	Category	Responses
Mechanic		2
Engineer		1
Builder		1
Distillery work		1
Farming/crofting		2
Engineering	STEM related	1
Game keeper		1
Work in renewable energy sector		1
Work at NASA		1
Digital media (gamer/You Tuber/influencer/games designer)		5
	Total	**16**
Nurse/doctor		5
Teacher		3
Police	Public sector	1
Firefighter		1
Soldier		1
	Total	**11**
Journalist		1
Footballer		3
Hairdresser		1
Young parent	Service sector	1
Shop assistant		1
Artist		1
	Total	**8**
	All responses	**35**

Table 2

Summary of responses to online questionnaires

		Plant science activities				Forensic science activities			
Theme	**Subtheme**	**Before**	**Proportion of answers**	**After**	**Proportion of answers**	**Before**	**Proportion of answers**	**After**	**Proportion of answers**
Epistemology	Scientific knowledge	17	.18	8	.10	1	.02	0	0
	Scientific process or activities	11	.12	15	.19	15	.30	30	.41
Topic-specific	Location/habitat/ context of science	7	.08	12	.15	9	.18	2	.03
	Factual knowledge, e.g., names of plants or tests and reagents	37	.40	17	.21	11	.22	30	.41
	People who do science	3	.03	6	.08	6	.12	4	.05
	Diversity	0	0	3	.04	0	0	0	0
Impact of knowledge	Utilitarian outcomes	6	.06	17	.21	6	.12	7	.09
	Affective response	11	.12	9	.11	0	0	1	.01
	Total	**92**	**1.00**	**80**	**1.00**	**50**	**1.00**	**74**	**100**

Only eight participants provided drawings as part of their response and those made at the plant science activities were considerably more detailed.

Changes in the participants' thinking were indicated by the changing proportion with which different sub-themes featured in their answers before or after the intervention. The most noticeable shift – brought about by carrying out some or all of the plant science activities – was away from emphasising scientific knowledge towards engaging further with the scientific process. This shift was also reflected in what the participants communicated about the topic under study, with fewer factual comments about plants and more said about the people creating the scientific knowledge. The emphasis on science as a process, rather than a static and unquestionable body of knowledge, enhances accessibility and is a powerful tool for engaging a wider audience (McComas, 1996). There were also increased references to habitat and the interactions between plants and animals. For an intervention designed to explore cultural diversity in science, it was surprising to find only three pieces of data referring explicitly to diversity in the post-intervention data. One possible explanation for this is that asking about what they knew about science signalled that the responses expected would resemble those required for a school science test. The other change shown by the data is a proportionately large increase in awareness of the usefulness of scientific knowledge. This would have been predicted given that the activities focused on food products from plants. Anecdotal evidence recorded in the field notes suggest that the everyday nature of the plant science activities made them accessible. One child exclaimed, 'It smells like Christmas' while sniffing the whole cloves, and many of the participants talked about the dishes they associated with the different spices. There was, however, only one explicit comment on the multilingual postcards, when a primary aged child observed, 'My granny uses this', when they saw the card in Urdu.

The forensic science activities brought about a doubling in focus on the scientific process. Responses regarding the science underpinning the activities showed a large drop in focus on context, a near trebling of the proportion of answers providing factual knowledge, such as the names of tests or reagents, and a reduction in references to the people who do the science. This content-rich form of forensic science may align with pupils' perceptions of school science. There was no reference to linguistic diversity or culture in the feedback. The most common reference to the context of the activities was several comments by teachers about their appreciation that the researchers had visited them in their very rural location, rather than asking them to travel to a centre of population. There was also satisfaction at being given previously translated material, as many Gaelic medium teachers find translating English language resources into

Gaelic very time-consuming. Disappointingly, given that the activity had been chosen as one of direct relevance, by the time the interventions ended there was no change in the participants' recognition of the impact of the knowledge generated by the activities. This was surprising given the literature, which advocates for culturally relevant pedagogy (Aschbacher et al., 2010; Cobian et al., 2024; Mensah & Moore, 2017).

A comparison of the differences between the two sets of activities showed that they both brought about a change in people's thinking about science in general and about the area of science under study. The forensic science activities were especially successful at increasing the participants' awareness of the processes associated with science, but there was also a marked increase in focus on the factual aspects of the activity and a correspondingly reduced focus on the context in which the science was situated.

Discussion

The major factor limiting the gathering of data on impact seems to have been time constraints and the inevitable tension between taking time from science communication activities to leave sufficient time for feedback. The relatively short duration of the interventions also limited the level of impact that the activities could be expected to exert. There was greater detail in the drawings arising from the plant science activities, which were gathered at a public event, where participants were able to take as much time they wanted over the activities and evaluation. Conversely, delivering the forensic science activities in a school setting inevitably meant that the participants had limited time, dictated by their timetable. As described previously, external factors create time pressures that mitigate the desire for truly inclusive pedagogy, which raises major questions about our beliefs regarding what the most important outcomes from education should be.

Similarly, time pressures limited the response rates to the questionnaires. Nevertheless, some trends do appear within the data. As might be expected of staff who volunteered to engage with an additional science activity, they expressed positive views about science in school and their teaching of it (Q1, Q2 and Q7). They also believe that their pupils enjoy science, with both STEM subjects and 'hands on' subjects being considered popular; science has the considerable advantage of occupying both categories. This popularity sits alongside a view of science as only 'sometimes hard' (Q8). The teachers appear to see themselves as the main source of awareness about the role of science in the wider world (Q4). They also identify, whether consciously or not, a disconnect between school science and professional science (Q9), but nevertheless believe in the scientific capacity of their pupils and entertain positive views regarding whether their pupils could make a scientific discovery (Q10). Allied to this, many jobs that use STEM subjects were identified as career aspirations, although whether this factor contributed to the choices cannot be known. Familiarity with people who do STEM-related jobs doubtless plays a part in this, since it raises 'science capital', although the disconnect between aspiration and future realisation remains a major barrier (De Witt et al., 2013).

The two sets of activities were quite distinctive in their design and execution. The two participating populations were very different in a number of important ways, so it is difficult to make a direct comparison. Despite this, the plant science activities were more closely related to everyday life and were designed to allow participants a high level of choice about how they tackled the activities they undertook. Although the activities could be linked to formal scientific theories, the explanations offered were determined by the aspects in which the participants expressed interest; for example, based on the questions they asked or the observations they made. In this respect, the activities could be considered to be complex, context-based science and were not driven by any single element of the school curriculum. The decrease in factual knowledge relating to the topic may reflect the fact that the activities were very different to those that the participants would associate with formal science instruction. On the other hand, the forensic activities were far more structured, with each activity illustrating one technique and one scientific concept, such as the way everyone has unique fingerprints and why. In this way, the delivery was much more akin to a standard school science lesson. Both the singularity of content and the predetermined outcome of the forensic science activities more closely resembled the format of formal science lessons. The approach may be reflected in the increased focus on topic-specific content shown on the postcards.

The participants' responses raise some interesting points about how science educators might set about working most effectively with culturally diverse audiences in future. Both sets of activities were designed and delivered in keeping with the criteria for generally inclusive science teaching (or knowledge exchange) and, additionally, to exhibit diversity identifiers. However, there was very little acknowledgement of the impact of the overt message about diversity in science. This raises important questions about whether such diversity markers may be viewed as superficial or tokenistic and disregarded (Alexiadou & Essex, 2015). Alternatively, they may serve as a general signal of intentional cultural pluralism, which, in turn, is associated with an improved diversity climate, in which both psycho-social impacts and academic outcomes are enhanced

(Schachner, 2019). This impact extends beyond those to whom any specific diversity signifier has personal meaning, as was shown in some of the anecdotal evidence. The implication of the latter explanation is that every science activity, whether formal or informal, would need to be matched very precisely to the cultural profile of the intended audience. It also treats diversity as a series of discrete categories rather than a complex and fluid aspect of society (Kraus, 2012). Such an approach would be both practically challenging and directly counter to the notion that education should broaden young people's understanding of their world and the different people in it (Biesta, 2010).

The generation of the sub-themes and themes suggests that the participants' notions about science fell into two categories: those relating to science in general and those relating to the specific topic being studied. There was a corresponding dichotomy of focus on the processes of science and the knowledge that arises from them, with a shift in the proportion of responses in the sub-themes from content, both general and topic-specific, towards the processes by which the knowledge is generated. Similarly, there was an increase in focus on the people who do science, which would facilitate further discussions about the ways in which science and culture are inter-related. Both groups showed an awareness of the consequences of scientific activities, but an increase in awareness of the impacts of science was only observed in response to the plant science activities. Interestingly, the forensic science activities did not provide evidence of an increased knowledge of social impact, despite their intended relevance to the young people's social and cultural context.

Conclusion

Efforts to explicitly involve diverse cultural groups via multilingual resources and the selection of culturally relevant topics resulted in slight changes in the participants' views of science, but did not result in an explicit articulation of the place of diverse knowledge in the pursuit of science. Nevertheless, there was evidence that these signifiers of diversity were noted and appreciated by a few participants and were not a deterrent to others. More significantly for future efforts to enhance social inclusion, the two sets of activities provide some evidence of how to bring about changes in thinking about what science actually is. Some of these changes could be expected to enhance engagement in science by those who are currently under-engaged. Noticeably, the set of activities that differed most from the format typically taken by school science brought about more changes in viewpoint that would be expected to mitigate the deterrent features of science. The study provides evidence of the benefits of a less content-driven approach to science, one that presents alternative ways of being scientific and presents science as body of knowledge to which very diverse people have contributed (and will continue to contribute). The findings suggest that easily assessed scientific knowledge is not the most inclusive version of science, nor is it ultimately the most socially sustainable. The implication of these findings for future practice is that the nature of science in the curriculum, and its associated assessment, may need radical review.

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Non-formal Science Education: Moving Towards More Inclusive Pedagogies for Diverse Classrooms

Genco Guralp[1], Martin McHugh[2] and Sarah Hayes[2]

The Diversity in Science towards Social Inclusion–Non-formal Education in Science for Students' Diversity (DiSSI) project aimed to provide a holistic perspective on diversity, focusing specifically on cultural and ethnic identities, language, socioeconomic background, gender, as well as differing levels of achievement. In particular, the work presented in this paper aims to tackle consciously the issues surrounding teaching and learning in socio-economically deprived areas through non-formal education. This paper presents the results of a pilot study that examined how students participating in non-formal education engage with multi-modal pedagogical approaches designed to address multiple dimensions of diversity via an intersectionality lens. Working with diverse groups requires varied methods; as such, a mixed-method approach was employed in the study to ensure the research team authentically captured and engaged with the lived experiences of the participants. The study aimed to generate best practices that augment the science capital of students, which are applicable across various contexts of diversity. The pedagogical approaches, while not novel in science education literature, were rarely utilised by the teacher and thus were rarely experienced by the students. Participants reported a greater sense of autonomy and ownership of the science through participation in the DiSSI programme. Preliminary results indicate an overall positive experience for students and teachers alike and offer insights into the overall lived experiences of participants, which inform future work.

Keywords: socio-economic deprivation, diversity, equality and inclusion, science capital, context-based learning

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Neformalno naravoslovno izobraževanje: približevanje inkluzivnejšim pedagogikam za raznolike razrede

Genco Guralp, Martin McHugh in Sarah Hayes

Namen projekta *Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity* (DiSSI) je bil zagotoviti celosten pogled na raznolikost, s posebnim poudarkom na kulturnih in etničnih identitetah, jeziku, socialno-ekonomskem ozadju, spolu pa tudi na različnih ravneh dosežkov. Cilj dela, predstavljenega v tem prispevku, je zlasti zavestno reševanje vprašanj, povezanih s poučevanjem in z učenjem na socialno-ekonomsko prikrajšanih območjih prek neformalnega izobraževanja. V prispevku so predstavljeni rezultati pilotne študije, ki je preučevala, kako se učenci, ki sodelujejo v neformalnem izobraževanju, odzivajo na multimodalne pedagoške pristope, namenjene obravnavi več razsežnosti raznolikosti skozi prizmo intersekcionalnosti. Delo z različnimi skupinami zahteva različne metode; tako je bil v študiji uporabljen pristop z mešanimi metodami, da bi se zagotovilo, da je raziskovalna skupina avtentično zajela in upoštevala življenjske izkušnje udeležencev. Cilj študije je bil oblikovati najboljše prakse, ki povečujejo naravoslovni kapital študentov in so uporabne v različnih kontekstih raznolikosti. Pedagoške pristope, ki v naravoslovni literaturi sicer niso novi, je učitelj uporabil le redko, zato so jih učenci le redko izkusili. Udeleženci so poročali o večjem občutku avtonomije in lastništva naravoslovja zaradi sodelovanja v programu DiSSI. Preliminarni rezultati kažejo na splošno pozitivno izkušnjo za učence in učitelje ter ponujajo vpogled v splošne življenjske izkušnje udeležencev, ki so podlaga za nadaljnje delo.

Ključne besede: socialno-ekonomska prikrajšanost; raznolikost; enakost in inkluzija; naravoslovni kapital; učenje, temelječe na kontekstu

Introduction

The value of diversity is well-documented for scientific research in general. Examining over nine million published papers and six million scientists, AlShebli and colleagues (2018) showed that scientific impact (measured using citation counts) strongly correlated with the ethnic diversity of researchers in a collaboration. Additionally, social diversity has recently appeared to be both a value and a challenge to be reckoned with in the field of science education (Mansour & Wegerif, 2013). Especially in urban contexts, science classrooms host a heterogeneous mix of students hailing from diverse backgrounds. These students study together with students that the teachers are traditionally more familiar with in their teaching experience, and from this perspective, the latter group may be seen as a 'dominant' one. Consequently, some students may experience pedagogical disparities as they belong to a minoritised group. The diversities in question may include *cultural and ethnic identities*, *linguistic ability (*including differing abilities in comprehending the language of instruction), *socio-economic class*, *gender*, as well as *differing levels of achievement.* As recently demonstrated by Archer and colleagues (2012), diversity categories such as *gender*, *class*, and *socio-economic background* heavily influence career decisions and science aspirations of students. Thus, if insufficiently addressed, diversity in science education can lead to the under-representation of minoritised populations, which in turn leads to significant social and economic inequalities. The Erasmus+ *Diversity in Science towards Social Inclusion* (DiSSI) project aimed to develop science education practices that address the pedagogical needs of a diverse body of students to contribute to more egalitarian and inclusive science classrooms.

Two important aspects of diversity are not sufficiently addressed in the current literature: first, most of the recent work on diversity tends to be *descriptive*; researchers aim to map how contemporary students with diverse backgrounds view or understand the nature of science, the school science curriculum, or examine the reasons behind the lack of interest in science that is observed globally (Avraamidou & Schwartz, 2021; Lee & Luykx, 2006; Aschbacher et al., 2010). However, what practising teachers need most are *pedagogical tools* that are available for them to make use of when teaching in a diverse classroom (Acquah et al., 2020). Second, much of the research on the issue of which type of interventions are most helpful in addressing disadvantages that arise due to diversity tends to focus on a *single dimension* of diversity, most notably *gender* (Wright and Delgado, 2023) or *race* (White et al., 2019). However, as will be argued in detail below, diversity is a *holistic* notion; specifically, the various categories of diversity do not appear in isolation, but they are present in each individual as a whole.

To develop a 'holistic' pedagogy, the DiSSI project singled out *five* specific dimensions of diversity, which the project partners have already built expertise on, and generated pedagogical approaches that are applicable in wider contexts by amalgamating this expertise. These specific dimensions are 1) linguistic diversity, 2) cultural diversity, 3) ethnic diversity, 4) socio-economic status, and 5) high-achieving students. Partners in the project each studied a single dimension of diversity and then exchanged and re-structured their pedagogical approaches to generate a set of strategies that can be employed in broadly generalisable ways.

In this paper, a pilot study that was conducted in Ireland as part of the DiSSI project is discussed. This paper has two specific aims. First, we aim to present a theoretical framework that provides a conceptual basis for developing pedagogical interventions for a diverse body of students. We believe that a solid theoretical understanding is essential for building pedagogical interventions, as this guides both their development and execution. Second, we aim to present the empirical results of our pilot project. The research and results presented in this paper are part of a general programme that was conducted in Limerick, Ireland. The main goal of our project in Ireland has been first to investigate which pedagogical practices are best suited to meet the science education needs of students from low socio-economic backgrounds and then examine how these strategies can be amended and improved based on the pedagogical practices the DiSSI partners developed to address diversity as a holistic notion. To this end, we have utilised a set of science workshops that were originally developed in a public engagement with a science setting aimed mainly at the *non-formal* sector,[3] in addition to workshops specifically designed for DiSSI. These workshops are designed to be conducted in in-school and out-of-school settings with post-primary students. Even though the content and the pedagogical approach of the workshops vary, they all involve practice-oriented 'hands-on' activities that provide 'agency' to the students that they may insufficiently experience in the school science setting. One example of these activities is the *Medicine Maker* workshop, in which students 'manufacture' dummy capsules using a capsule-filling plate and other equipment. The main guiding question for our study has been to

3 The DiSSI project focuses on *non-formal learning* as it provides the researchers with greater flexibility to design and test teaching strategies for diverse students. The OECD (2012) situates the non-formal sector between fully structured formal learning and a 'never organised' informal. The non-formal sector generally differs from the informal as it may be organised and structured. However, it has a 'voluntary' aspect that is not usually considered as part of formal education. (Garner et al. (2014) note that partial overlaps in these sectors seem unavoidable, given the difficulties in providing a sharp distinction between them. Thus, instead of seeking such distinctions, we prefer to emphasise the learning continuum that these sectors span. Our non-formal interventions do incorporate formal elements, such as the interventions taking place in a school lab with the teacher being present at all times, as well as many informal learning opportunities that context-based, collaborative hands-on activities present.

examine the effect of these workshops on the interest as well as the science-related aspirations of the students.

Theoretical Framework: Intersectionality, Science Identity, and Science Capital

The DiSSI project is specifically oriented towards building a pedagogical repertoire for science education challenges in contemporary societies that are marked by various forms of diversity as a result of globalisation and international immigration. The social and political consequences of these developments for science education have been theorised in various ways and from various perspectives (Carter et al., 2017; Marosi et al., 2021). In our study, we have focused on three conceptual pathways that are interlinked via a common theme of *diversity* to guide our research and analysis. These are the frameworks of *intersectionality*, *science identity*, and *science capital*.

Intersectionality

To conceptualise the holistic approach to diversity that DiSSI emphasises, we have adopted *intersectionality* as a theoretical lens. The concept of intersectionality was first introduced by Kimberlé Crenshaw in her study of the discrimination experienced by black working-class women in the US legal system (Crenshaw, 1989). According to Crenshaw, identity politics that solely focuses on *race* or *gender* for achieving political equality misses the ways different forms of identities may intersect and become a source of oppression. Thus, for Crenshaw, adopting a single categorical lens when analysing discrimination and oppression would marginalise those people who possess more than one category of identity and would thus make claims that do not stem from singular identity categories unintelligible. Here, the analytical work to be conducted is to examine how the many dimensions of identity shape the experiences of discriminated individuals. This framework is readily applicable to a science education context. Adopting an intersectionality lens, we may expect, for example, a non-white female student and a white female student to experience different forms of discrimination. However, a problem seems to appear at this juncture: if intersectionality implies that each individual is uniquely positioned vis-à-vis the discriminatory practices that lead to inequalities, how could it be possible to develop pedagogical strategies that are context-unspecific and hence could counter these practices for *everyone*. There are two specific constructs we found helpful in this context: the constructs of *science identity* and *science capital*. Both these constructs put emphasis on the *agency* of the individual and facilitate the generation of practices that enable the students to assert their *autonomy*. As we argue below, a pedagogical practice that puts science identity at the centre and aims at augmenting the science capital of the students can both incorporate intersectionality and overcome the challenges it poses for science education.

Science Identity

Science identity has been discussed by numerous authors since the early 2000s.[4] There are several key reasons why science identity is important to consider when working with students who are socio-economically marginalised. It has been well established that most post-primary students associate the scientist with a white male figure in a lab coat (Chambers, 1983; Ferguson & Lezotte, 2020). Thus, pedagogical interventions that aim to include students cannot be successful by merely generating means of transferring scientific information in more accessible ways unless the students recognise that their own competencies, personal histories, perspectives, or interests are represented in science. A science identity lens can help us achieve this goal, as taking the science identity of the students into account would enable the researchers to recognise and incorporate into their practice the individual students' science representations.

In an influential article, Heidi B. Carlone and Angela Johnson studied the science experiences of women of colour and proposed science identity as an explanatory lens to understand how scientists from marginalised backgrounds 'experience, negotiate and persist in science' (Carlone & Johnson, 2007, p. 1188). They found science identity to be a key construct that can account for individual agency in its relationship with the existing societal structures and modelled it in terms of three components: *competence*, *performance*, and *recognition*. This conceptualisation is based on a 'prototype' person with a strong science identity. As the authors argue, such a person would have a certain level of competency in science topics, possess the necessary skills to perform this competency, and finally be recognised, as well as recognise herself, as a 'science person'. A key finding of Carlone and Johnson is that recognition of oneself as a science person critically depends on how one is perceived by meaningful others (established scientists or members of one's own community), and in the case of negative recognition, a student may re-negotiate their science identity through strategies such as re-defining the very meaning of 'science'. Thus, one possible pedagogical approach that could be utilised when working with minoritised students is

4 For a general introduction to recent work on science identity, see the edited volume by Holmegaard and Archer (2023).

pluralism: there can be more than one definition of science, or what it means to be a scientist, and various different kinds of activities can be considered as 'scientific' depending on the context. On the basis of this observation, we have included a plurality of topics and pedagogical approaches in our workshops.

In a recent conceptual paper, Lucy Avraamidou points out that intersectionality is a 'useful conceptual framework and methodological tool for examining *the relationality and multiplicity* of science identity' that has political implications (2020, p. 328, added emphasis). These implications are especially concerned with 'the purpose of addressing inequalities and promoting goals related to equity and social justice' (Avraamidou, 2020, p. 331). In line with Avraamidou's approach, we situate science identity within an intersectionality framework, which makes explicit how various identities that the students possess interact and contribute to the multiplicity of their science identity.

Science identity has been studied from various different perspectives, ranging from quantitative studies that aim at instrument development and validation (Chen & Wei, 2022) to studies exploring the social justice and equity angle on this concept, focusing on students from minoritised backgrounds (Harper & Kayumova, 2023). However, the question of what forms of pedagogical interventions can be developed that would help students from minoritised backgrounds to build more robust forms of science identity has been underexplored. In the design and conduct of our workshops, we were attentive to enabling the students to recognise their own competencies and capabilities with which their relational but singular identities equipped them. The intersectionality/science identity lens provided a solid theoretical grounding for our work and enabled us to explore the socio-political dimension of working with students from marginalised backgrounds. Nonetheless, as our guiding aim has been to explore pedagogical strategies for practitioners, a more tangible theoretical framework is required to measure and analyse the effects of the interventions. The *science capital* framework developed by Louise Archer and colleagues provides a suitable setting for this, which allowed us to ask what forms of interventions can augment the science capital of students from diverse backgrounds (Archer et al., 2015; DeWitt et al., 2016; Calabrese Barton et al., 2021).

Science Capital

The *science capital framework* is built on Pierre Bourdieu's sociological theory, which extends the concept of economic capital to social and cultural spheres. Bourdieu introduced the concept of culture to explain how education contributed to the reproduction of social inequalities by 'legitimating class differences' (Bourdieu & Passeron, 1990, p. 164). More generally, according to Bourdieu, explaining the hierarchical structure of power relations in society and how this structure reproduces itself from one generation to the next requires taking into account the dynamics of social and cultural capital (such as how these are transmitted in the family, or through educational institutions). Following this conception, Archer and her colleagues proposed the concept of *science capital*, understood as the science-related forms of social and cultural capital, as a useful and measurable construct to analyse the issue of unequal patterns in the participation rates in science education, especially of students from underrepresented groups. As an explanatory framework, science capital sheds new light on these 'uneven patterns in science participation' and thus constitutes a possible basis for intervention (Archer et al., 2015, p. 923).

The concept of science identity can be suitably placed within a Bourdieusian concept of *habitus* (DeWitt & Archer, 2015, p. 157). As Bourdieu characterises it, habitus is 'spontaneity without consciousness?': it is the subjects' ability to navigate the world without the necessity of consciously following explicit rules in each step (Bourdieu, 1990, p. 56). Thus conceived, habitus comprises 'systems of durable, transposable dispositions [...] predisposed to function as [...] principles which generate and organize practices and representations.' (Bourdieu, 1990, p. 53). These are the practices and representations one 'internalises' through familial and other social interactions and readily deploys in social settings. Thus, one sees that the components of the science identity model that Carlone and Johnson propose (2007) can be seen as science-related conceptualisations of habitus:

For example, a scientist presenting her work at a conference must use language according to prescribed norms, dress and interact in certain ways, and demonstrate that she thinks in certain ways for others to recognise her performance as appropriately 'science-like' if she wants to be considered a scientist (p. 1190).

A person with a strong science identity would exhibit a scientific habitus that would enable her to navigate seamlessly the scientific field. Thus, in planning interventions aiming to augment the science capital of students' one should be aware of this 'unconscious spontaneity' and incorporate it into the design of the intervention elements that would enable the students to equip themselves with tools that would make them 'feel at home' in the scientific field.

The Irish Context and the Research Setting

In Ireland, post-primary education is divided into the *junior (age 12-15/16)* and the *senior (15/16-18)* cycles. It should also be noted that science is not compulsory in Irish schools at the post-primary level. Schools with a higher provision of students from marginalised backgrounds are less likely to make junior cycle science compulsory for students, leading to lower numbers of these students taking science. Students who study science in the junior cycle study general science (physics, chemistry and biology) with a *nature of science* strand. Albeit short, this strand includes key topics such as scientific method, science in society, and science communication.

The Pobal HP Deprivation Index,[5] which provides a measure of the affluence or disadvantage of a particular geographical area in Ireland, was utilised to locate the schools in Limerick which serve areas that are socio-economically most disadvantaged (Haase & Pratschke, 2017). Additionally, this index was cross-matched with the register of 'Delivering Equality of Opportunity in Schools (DEIS)'.[6] A study by Smyth et al. (2015) noted that 'Schools classified as DEIS have a much higher concentration of disadvantage than other schools and also cater for more complex needs, with a greater prevalence of students from Traveller backgrounds, non-English speaking students, and students with special educational needs' (p. vii). Limerick, where this study is conducted, has the highest relative deprivation score in the country, indicating that communities in Limerick are among the most disadvantaged. Thus, when we consider Limerick through the lens of the Pobal social deprivation index, we observe that the city has areas with high lone-parent ratios and low third-level education, income, and class. These are merely indicators, but they point to significantly at-risk populations.

In our pilot study, we conducted six workshops over the course of eight weeks at an all-girls school in Limerick, Ireland. Located in an urban setting, the school caters to mostly students from socio-economic backgrounds. The school has a sizeable population of students from immigrant communities, as well as students with Irish Traveller heritage. Irish Travellers, or the *Mincéiri*, is an ethnocultural group in Ireland that is recognised as an ethnic minority (Haynes et al., 2021).

5 POBAL is an Irish government organisation that is responsible for the management and support services of 38 programmes in the areas of Social Inclusion and Equality. ('Pobal' is an Irish word meaning 'community' or 'people'.) The index utilises information from the Irish census, such as 'employment, age, educational attainment'. https://www.pobal.ie/

6 In Ireland, certain schools serving disadvantaged populations are supported through the Delivering Equality of Opportunity in Schools (DEIS) programme that was introduced in 2006, which identified schools based on school principal reports of the profile of their student population. Information from large-scale surveys, such as the Growing Up in Ireland study, 'confirms that DEIS schools differ markedly from non-DEIS schools in terms of the social class background, parental education, household income and family structures of their students' (Smyth et. al., 2015, vii).

Literature on Diversity and Students from Traditionally Excluded Backgrounds

The influence of socioeconomic status on the declining rates of science participation has been established by several studies (Gorard & See, 2009; Cooper et al., 2020). In a recent paper that draws on data from 4300 students, Cooper and Berry (2020) use the science capital construct and explicitly link socioeconomic status with a strong science identity. There are studies that either explicitly or implicitly assume an intersectionality lens and study how students from marginalised backgrounds develop or negotiate their science identities. These include both survey-type quantitative approaches (Keller et al., 2023) as well as qualitative studies based on ethnographical methods and/or in-depth interviews (Barton & Tan, 2018).

In a paper that builds on these studies, Kayumova and Dou (2022) raised a critical concern in working with students from marginalised backgrounds. For these authors, simply aiming at increasing the science capital of the students or attempting to strengthen their science identities would imply an implicit legitimisation of the dominant ontologies that are part of the very social structure that marginalises these students in the first place. As the authors write:

> If science spaces continue to operate through dominant cultural norms and values, *merely providing access to materials or opportunities to participate in science will not make the kind of changes we seek*... From this perspective, the design of learning ecologies must create conditions of possibility that center on identities, community histories, relations, and experiences of racialized youth from nondominant communities rather than erase them (p. 1113, added emphasis).

What these authors point out is that without recognising the perspective of the marginalised communities that a social justice-oriented science education research aims to reach, we would be 'normalize[ing] deficits and educational hierarchies' (Kayumova & Dou, 2022, p. 1098).

These considerations are directly relevant to the research context that this paper presents. A study by McCoy and colleagues (2022) notes that unconscious bias can give rise to issues such as mothers perceiving boys' abilities to be higher than those of girls. This finding was also true for teachers. A similar study indicated that parental expectations for young people with special education needs are much lower than those of the young people themselves (Mihut et al., 2022). Thus, parental expectations and engagement can have a significant effect on students' academic outcomes. In the context of students from low socio-economic backgrounds, low parental expectations and dominant cultural norms with which the school science operates may be related. We acknowledge the possible tension between our research aim of generating best practices that augment the science capital of students and the critical perspective we raise here on science capital, following Kayumova and Dou (2022). Nevertheless, it should be emphasised that despite its potential pitfalls, the science capital framework constitutes a valuable tool worth exploring further in the context of social disadvantage.

We pursued the following set of guiding principles in our quest to create pedagogies that target the science capital of the pupils. First, we examined the four general principles of the science capital teaching approach and generated pedagogical strategies to implement them (Godec et al., 2017). These principles include *broadening what counts*, personalising and localising, eliciting, valuing, and linking, and *building the science capital dimensions. Broadening what counts* involves 'creating spaces where all students feel able to offer contributions from their own experiences, interests and identities, knowing that they will be valued' (Godec et al. 2017, p.19). As a concrete broadening strategy, we employed the Family Resemblance Approach (FRA) for the nature of science (NOS) (Dagher & Erduran, 2016). The FRA approach incorporates three layers to conceptualise NOS. At the core, epistemological aims exist, social and professional aspects exist, and finally, the politics of science exists. Incorporating the FRA model, we broadened the pedagogical basis and the epistemic content of the activities that we could conduct with the students, such as a debate on the ethics of science, a discussion on space travel, or histories of science that are not usually included in the curriculum. Hence, NOS considerations can make science learning appealing to diverse learners. Following the principle of *localising*, which aims to contextualise science in ways that relate it to the students' lives, we have sought ways to make our activities open-ended and moderately to minimally structured so that the activities can be amenable to the students' perspectives. Thus, all the activities were designed in a context-based way that incorporates science, society, and technology themes. As has been emphasised in the literature, building a community of learning is key to creating a space of trust with students from diverse backgrounds (Gay, 2002b; Considine et al., *2017*). Thus, we also incorporated elements of group work and peer review so that the students could interact with their peers in a non-competitive manner towards building trust. Finally, based on the evidence showing the positive effects of inquiry-based learning for socioeconomically disadvantaged youth, we incorporated elements of inquiry-based learning that do not presuppose any prior knowledge (Creghan et al., 2015; Cuevas et al., 2005; McManus et al., 2015; Summerlee, 2018.)

Research questions

Our project hypothesises that appropriate pedagogical approaches, grounded in theory, can augment the science capital of students from low socio-economic backgrounds. This augmentation can occur by enabling the students to perform a positive science identity, meaning to see themselves (and to be recognised by others as being) science people, as well as developing self-efficacy by becoming more confident in their abilities (Avraamidou, 2020). Building on these conceptual characterisations of several key constructs in science education research on students from traditionally excluded backgrounds, we aimed to understand what kinds of non-formal interventions are best suited for these students. To this end, our main research questions are:

A. What are the impacts of the interventions on participants (both the students and the teachers)?

B. What kinds of new practices (or variations on the existing ones) can one introduce to best target the science capital of students during non-formal and informal pedagogical activities? In particular, does the specific combination of the pedagogical approaches utilised in the programme properly target students' science capital?

Method

This study employed a mixed methods approach. The rationale for this was to ensure that the study took a holistic perspective, enabling the construction of a broad, generalisable picture (Borg & Gall, 1983, p. 27) through quantitative measures while also fostering a deeper richness of data through qualitative methods. It has often been acknowledged that research studies must be 'governed by the notion of fitness for purpose' (Cohen et al., 2007, p.78). Therefore, when choosing a methodological approach, the aims of the study and the research questions were key considerations. This aided in focusing on the study and acknowledging the complexity of the research environment in which it was situated. The study identified that dimensions of diversity were typically treated in the singular throughout the literature and sought to draw from the theoretical underpinnings of intersectionality to explore and understand better the lived experiences of teachers and students across varied dimensions of diversity. To better understand this, both quantitative and qualitative methods were utilised, as a mixed-methods approach served the requirements of the study most effectively.

Participants

Once we had reviewed the Pobal HP Index and the DEIS school database, we concluded that there were four urban schools in the locale to which we should offer the programme. We contacted teachers in these schools, and one school was particularly interested in participating. It was a DEIS status single-sex female intake post-primary school in an urban setting. This urban school caters mostly to students from low socio-economic backgrounds, and it has a sizeable population of students from immigrant communities, as well as students with Irish Traveller heritage.

This pilot was implemented with one first-year class (ages 12–13) of female students. The class size is 21, but with regular absenteeism, we have data from a lesser number of students (ranging from 13 to 18 in different workshops)[7] and the class teacher who was present in every session. The research data collected with this group consists of 1) exit cards collected after each intervention/workshop, 2) a pre- & post-test DiSSI Instrument administered at the beginning and the end of the intervention series, and 3) a teacher interview. All survey data is treated anonymously.

Instruments

For quantitative analysis, we employed a Likert-style questionnaire specifically developed by the DiSSI project. Qualitative data collected consists of 1) exit cards collected after each intervention/workshop and 2) teacher interviews. The initial plan with the study was to administer a pre- & post-test after every workshop to align with the evaluation of our project partners in Germany, Scotland, Slovenia, and North Macedonia. However, after the first test was issued, the research team realised that the literacy issues in the class were more extreme than we had originally anticipated, and certain scales (*motivation* in particular) were challenging for students to interpret, and they required a great deal of aid from the instructing researcher, teacher, and classroom assistants. This led to a reconsideration and revision of the approach, and the team decided to incorporate *exit cards* into the evaluation portfolio. The pre- & post-tests were utilised at the beginning of the set of the six-workshop programme and again at the end of the programme, rather than after each workshop. As mentioned, a limitation of these surveys is the challenges they posed for the group: the interpretation of questions required support from the researcher, teacher, and classroom assistants, and one child participating was illiterate. This

7 See Table 1 for the number of students that attended each workshop.

explains, in part, the limited sample size from the class of 21 students. In addition, the research team acknowledged that certain elements of the survey could not be clearly interpreted (e.g. motivation) as the length of the statements was too long and complex for the students. To obtain quick and unobtrusive data at the end of each workshop, *exit cards* were utilised (sometimes referred to as exit tickets) post-workshop. Exit cards are short surveys specifically designed to be easy to comprehend and answer in that those using them have flexibility in how they answer elements of the exit card; they can write or draw. Emanating from educational settings, they are an instrument with which students are familiar. Given this, they are optimised for efficiently attaining the student voice in an anonymous manner (Fowler et al., 2019).

The DiSSI pre- & post-test is an instrument that was developed by the DiSSI project team and included items chosen from the following Likert scales:

1. Interest in the subject (OECD/PISA, 2009). (DiSSI Instrument Items (1–5).
2. Career aspirations in science (Kier et al., 2014). (DiSSI Instrument (6–12).
3. Self-concept towards science (OECD/PISA, 2009). (DiSSI Instrument (13–18).
4. Motivation (Ryan & Deci, 2000). (DiSSI Instrument (19–28).
5. Situational interest (Chen et al., 2001). (DiSSI Instrument (29–37).

The pre-test included the items (1–28)] The post-test included all the items from the pre-test, in addition to items (29-37) that aim to measure the situational interest at the end of the six-set workshop programme. While there were significant issues among the students in comprehending the pre-test (as noted above), the items in ‘Interest for the subject’ (OCED/PISA, 2009) and ‘Motivation’ (Ryan & Deci, 2000) were particularly problematic due to the longer sentence structure; as such, the research team had to develop additional supports for the students in order to enable them to access and respond to the survey instrument more fully in the post-test.[8]

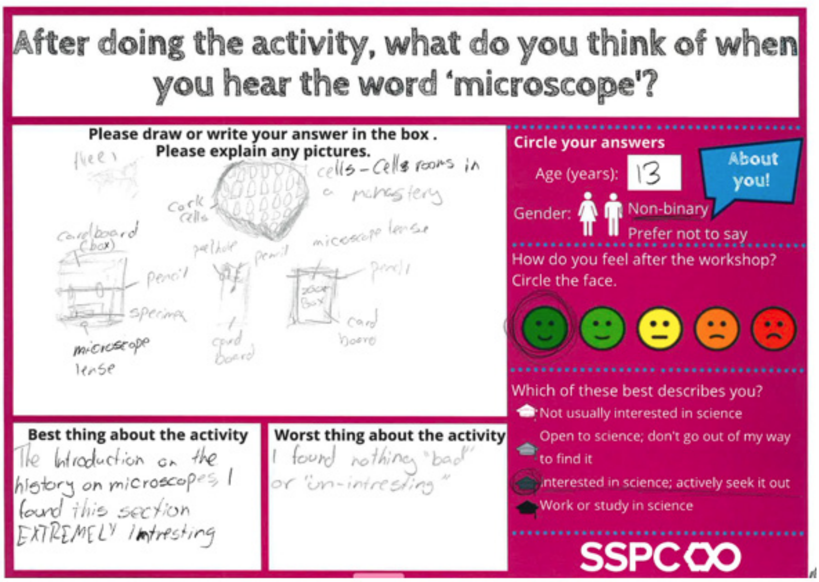
The use of exit cards as an evaluation tool for an earlier version of one of the DiSSI workshops (Medicine Maker) is described in (McHugh et al., 2022). However, these were further amended after a ‘knowledge sharing meeting’ was held with the DiSSI Scottish team. The exit card starts with a core question that can be adapted to each individual workshop. To support literacy issues and ensure student voices were heard, we included a section where the students are

8 The data for ‘Interest for the subject’ and ‘Motivation’ items can be found in the Tables 5 and 6 respectively, in the Appendix.

allowed to draw as well as write. Two sections asking the ‘best thing’ and the ‘worst thing’ about the activity are included, which encourages the students to write singular words (as opposed to sentences with which they have difficulty). The best-worst contrast enables the students to focus on multiple aspects of the workshops and aims to foster critical thinking.

We also incorporated a science capital measure prompted by the question ‘Which of the best describes you?’; however, the researcher observations indicate that the students’ level of engagement was not nuanced enough to give us a sensible measurement in the pilot. Exit cards were issued to all students at the end of each workshop, and they were given time and freedom to complete (see Figure 1.)

Figure 1
An example of a DiSSI Ireland Exit Card



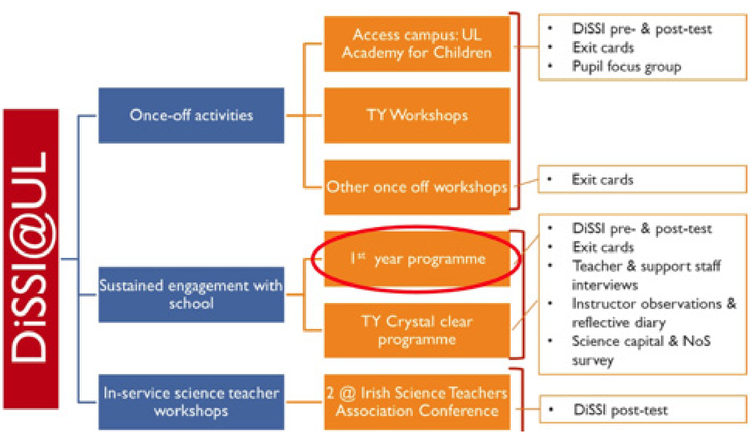
For the analysis of the exit cards, thematic coding was used (Saldana, 2015). First-cycle coding was undertaken by one of the authors (MM), and a consensus was achieved in a group discussion among the researchers.

Three semi-structured open-ended teacher interviews were conducted at the end of the programme (two teacher interviews and one interview with the Special Educational Needs teacher who supported the teaching). The teacher interview questions were developed by the research team with the aim of eliciting teachers' views on the main challenges of teaching at a DEIS school where the majority of the students come from 'low' socio-economic backgrounds, as well as the teachers' perspective on the impact of the workshops both on them and on the students. The guiding questions focused on the impact of the workshops on the teacher's pedagogical practice and her observations on the science interests and aspirations of the students. The interviews were analysed using thematic analysis as this is a flexible method that is deemed appropriate for a pilot study (Clarke & Braun, 2017).

Research Design

The main methodological approach in the DiSSI project is developing non-formal sector interventions that support the science education needs of a diverse student body. To this end, we have focused on pedagogical strategies that would foster inclusivity. The programme of workshops developed covers a range of topics across the Junior Cycle (12–15 years) general science curriculum, with varying lenses leaning towards physics, chemistry and biology content depending on the workshop and pedagogical approaches that would both link to the curricula for the course and aid with the overall goals of the DiSSI project. The overall Irish DiSSI programme is illustrated in Figure 2, with the pilot of the first-year programme (circled in red) presented here.[9]

Figure 2
The DiSSI programme at the University of Limerick (UL)



9 In the figure, 'TY' stands for transition year, which is a one-year programme between Junior Cycle and Senior Cycle. It is an unexamined year without a set curriculum that aims to help students become independent learners. We conduct several types of workshops and programmes with the TY year students.

In our pilot study, we conducted six workshops over the course of eight weeks (accounting for school holidays in between). The workshops were individual units and not interdependent, as this school had noted challenges of high levels of absenteeism. Therefore, the team determined that individual workshops which could be delivered as standalone units, but also interconnect via their pedagogical approaches were the most appropriate. The workshops and elements of the pedagogical approaches embedded in each are outlined in Table 1 below.

Table 1

Overview and descriptors of workshops implemented throughout the 8-week intervention.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Workshop	Medicine Maker	Gross Germs & Bizarre Bacteria	Crystal Drop	Ethics of Animal Research	NASA Survival on the Moon Activity	Inventing the Microscope
Pedagogy	Context-based Inquiry	Hands-on Inquiry	Open Ended Inquiry	Nature of Science*	Nature of Science	History of Science
Delivery Mode	Structured Activity	Moderately Structured Activity	Minimally Structured Activity	Argumentation / Minimally Structured Activity	Argumentation/ Minimally Structured Activity	Minimally Structured Activity
Epistemic Content	Authentic Science	Applied Science	Basic Science	Ethics and Politics of Science	Peer Review	Nature of Science
Relevance	Science and Society	Implicit Nature of Science	Science and Technology	Science and Society	Science and Technology	Science and Society
Number of students in class & evaluation methods	16 Exit Cards Pre-test	13 Exit Cards	17 Exit Cards	13 Exit Cards	16 Exit Cards	18 Exit Cards Post-test

*'Nature of science' is considered both a pedagogical tool and epistemic content during the workshops.

Results

The Research Context

As mentioned above, the team triangulated the data collected to provide a clearer and more holistic picture of the student experience. The data were examined through the lenses of the research questions, with additional foci on science identity and science capital. This will be elaborated upon in the discussion.

In order to set the context for these results, the following excerpt from the teacher interview is important. During the interview, we asked the teacher how she thinks the socio-economic background of the students affects their performance. In response, she explained:

You have some that are really poor, had a poor background, and they don't seem to progress as quickly as the others […] They just, you'll have the 1 in 10 that will do well, and the school will be trying to support them if there is something they don't have or something they need. But some, you just can never, you can never help them, because the home situation is affecting them so much. So, for example, they may not have a study place. An area at home to study that's safe or that's noise-free, so the school will try and provide a quiet place for them to study. Or you might have ... their parents may be in jail. We would have a lot that are living in a hotel.[10]

During an exam week, a 'home-school' liaison would go to the house of a student to provide them with a study space outside their home. As the teacher explained, this person would:

> […] knock on the door trying to get the child out to go and sit their exam. Because the parents are just, they are not involved; they might be incapacitated for whatever they've taken or done. Some of the home situations would be dreadful. And it seems to be, if that's the situation, we really struggle to help them, or help them do well. Or we'll get them so far, and then they'll go, 'Nah, I'm gonna drop out of school'. We would have a high number of drop out, we would have a high number of school refusal […] So maybe 1 in 10 we manage, with a really poor background home environment, we manage to save them, I would say.

Here, the class teacher highlights the challenges that both the students and the school face in terms of the home environment, social surroundings, and

10 After our interview, the teacher explained that the students who live in a hotel are from families who are experiencing homelessness and are waiting on housing, so they are temporarily placed in hotels. These families are in a social housing waiting list.

school setting. The challenges of data collection processes in this research context of working with low-income students necessitated modifying the initial plan of using the pre- and post-survey instrument at each intervention. The researchers decided to enrich their data using exit cards, teacher interviews, and researcher reflections, given the literacy issues encountered by the students, which made the project surveys more challenging to administer.

Main Research Outcomes

When discussing the impact of the programme on the students, the class teacher noted that a particular highlight for her was that the students were mentioning the workshops at home. She also noted that this is highly unusual for this group of students and for the parents, and she believed this to have a particularly positive impact, inferring it was increasing students' attitudes towards and interest in science. When asked about the possible impacts the workshops had on the students, the teacher responded as follows:

> So they definitely want you teaching them instead of me [laughter.] [...] So they definitely have a peak in interest in science. Even the really weak ones. If they are leaving at the end of the year saying, 'Jeez, I love that about science,' I think we are winning [...] The fact that they are talking at home about 'we did this today in science,' and at the parent-teacher meeting in January, I probably forgot to tell you that, I would have spoken to all the parents and asked, 'Have they told you that they are doing a workshop, you know, with a guy from the University of Limerick.' And these are children from very poor backgrounds as well, the parents having very little interest. I'd say 90% of them had heard about it. Like that's massive. Yeah, like that doesn't happen. Cuz I might say, 'Did they tell you I brought in a set of sheep lungs for science week?' and they go, 'No, I've never heard anything about it.' That's really good, the fact that they are talking about science at home, in the homes of these children are going to, is massive, cuz it doesn't really happen.
>
> So they are talking about it at home, and 90% of their parents have heard about the workshop, which is brilliant. So you are winning when they are doing that. I think they are leaving at the end of this year, and most of the students, in their heads, really enjoyed science. So then they come in September with a positive attitude about it.

From this excerpt, we can infer the positive impact of the workshops on the science capital of the students. This interpretation also agrees with results from the exit cards, with one of the themes emerging from the coding being the 'affective'. In vivo, codes such as 'Satisfying' and 'Feel like a scientist' came through the data.

Another input from the teacher that should be noted is that, for many students, science is a subject that 'when they come in in September, they are excited about ... cuz it's different, but they think that they are gonna be blowing things up.' As a result, the students 'get a bit deflated when it is not all hydrogen bombs or things on fire or whatever.' When students experience aspects of school science such as learning theory, their interest levels go down. Nevertheless, the version of science that the workshops present is different from the 'school science' the students are familiar with, in almost contradictory ways. To give one example, whereas the school science is presented by the teacher in a more controlling manner, the workshops gave considerable agency to the students. The teacher elaborated on this point while also emphasising how being given autonomy in the school lab improved the practical skills of the students and the way this contrasts with her way of teaching:

> At the end of it all, I think their practical skills were brilliant, like really good. Because I think in the first year I don't, maybe I don't give them enough to do because I am nervous. I won't let them near the Bunsen burner; I don't want them to break something; I am giving them the plastic stuff so that they don't wreak the place. I definitely think that their practical skills are massively improved compared to ... the start of the year. Perhaps better than if I was just teaching them, because you [i.e., the researcher instructor] just give it a go and let them at it. Whereas I am very controlling ... You are better to go, 'No, no, just let them figure it out.' I probably don't let them figure out enough ... I need to let them spill it ... I have gotten more confident in the fact that I can give them something and they can figure it out. I think their interest in science has gone way up.

Thus, 'school science' and 'workshop science' are almost contradictory to each other, and this contrast appears in the data.

The second element of the survey, Career aspirations in science (Kier et al., 2014), indicated modest increases on both sides of the scale, with slightly fewer in the 'Neither agree nor disagree' category post-test (note that two additional students were present for the post-test, and one student who was present during the pre-test was absent for the post-test) (See Table 2).

Table 2
Results of survey instrument items on 'career aspirations in science.'

Career aspirations in science (Kier et al., 2014)		Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree% (n)
		Pre-test, *n* = 16			Post-test, *n* = 18		
6.	I plan to use science in my future career.	25% (4)	56% (9)	18% (3)	39% (7)	28% (5)	33% (6)
7.	If I do well in science classes, it will help me in my future career.	54% (8)	33%(5)	13% (2)	61% (11)	17% (3)	22% (4)
8.	My parents I would like it if I chose a science career.	27% (4)	67% (10)	7% (1)	39% (7)	39% (7)	22% (4)
9.	I am interested in careers that use science.	46% (7)	27% (4)	27% (4)	50% (9)	17% (3)	33% (6)
10.	I have a role model in a science career.	31% (5)	31% (5)	38% (6)	22% (4)	17% (3)	61% (11)
11.	I would feel comfortable talking to people who work in science careers.	75% (12)	25% (4)	0	35% (6)	30% (5)	35% (6)
12.	I know of someone in my family who uses science in their career.	37% (6)	19% (3)	44% (7)	50% (9)	6% (1)	44% (8)

Once again, this data, in isolation, does not give a complete picture; however, coupled with the teacher interview and exit cards, it aids in building a broader impression of the impact of the programme. From the survey data, it appears that student career aspirations have modestly shifted towards the positive, but also that their understanding of a career in science and of the work of a scientist has also been enhanced, thus better enabling them to make a shift in either direction. One item (11) signified a large decline in students' comfort levels in speaking with people who work in science careers. This is notable, and as this is a pilot study, it will be explored further in subsequent student focus groups. Exit cards revealed a large number of drawings or interpretations of people doing the activities/experiments that were at the centre of the workshop, in addition to technical drawings with the correct interpretation, along with new vocabulary and terminology. This is believed to be important, with the correct use of new vocabulary and the use of drawing to explain the work, *rather than the pressure of writing* about the activities to report them, offering ways for the students to demonstrate their knowledge and understanding outside of traditional formal routes. The exit cards paint a picture unlike what the research team has previously noted with workshops with other groups (McHugh et al., 2022). In previous workshops, 'relevancy' as a theme appeared prominently; however, this was not observed in the pilot group.[11] It appears that student career aspirations have modestly shifted towards the positive, but also that their understanding of a career in science and of the work of a scientist has also been enhanced, thus better enabling them to make a shift in either direction. 'Relevancy' not emerging in this group may be explained by background and environment: the students do not have the prior knowledge and experience to make connections between the workshop content and daily life. In recognition of this, we attempted to lower the barriers between the students and authentic science content and build exposure.

In this pilot study, a clearer picture of the Nature of Science emerges with students noting abstract elements such as the history of science, philosophy, morality, ethics, debate, or novelty. Additionally, the exit card data showed enhanced scientific language among the students. This is noteworthy, as in one instance at the beginning of the workshops when the researcher referred to the concept of 'explanation', a student retorted, saying that she does not understand the meaning of this term as it is a 'big word.' As a result, a significant portion of the instruction during the workshops was devoted to discussing the meanings of these 'big words' used in the science content of the workshops or the survey instrument.

Interestingly, and in contradiction to the teacher's opinion, the students have a mostly positive *self-concept towards science* in the pre-test (Table 3). Their self-concept towards science actually decreased marginally in most instances, indicating perhaps that they were either more challenged by the workshops or found them more difficult than their typical school science class.

The teacher also acknowledged that the pedagogical approaches were important for the students. In particular, concerning one student, she reported the following:

> There was another one that I said to you, an L2LP [Level 2 Learning Programme] student. A Traveller background. So is sitting, no exams. Actually, I can't read and write, and I was super excited about some of those practicals if you remember. Do you remember the person I am talking about? […] Yeah, she was mad keen to get going and came up to the top bench, if you remember. And actually concentrated for 80 minutes and did that activity. And I said, 'I am blown away with this because this one breaks my heart.' Not that she is terribly bold, but she is just not able to access whatever we are doing.

11 By 'relevancy', we mean students making the connections between what they were studying and things that were personally relevant or noting the relevance of the work by linking it to the news or to their parent's jobs.

For this student, accessing traditional lessons in any form was particularly challenging. However, during the DiSSI programme, the student was very engaged, yet her voice was not represented in the pre-post-test due to her literacy issues.

Table 3

Results of survey instrument items on 'self-concept towards science.'

Self-concept towards science (OECD/PISA, 2009)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)
	Pre-test, *n* = 16			Post-test, *n* = 18		
13. Learning advanced science topics would be easy for me.	44% (7)	25% (4)	31%(5)	35% (6)	24% (4)	41% (7)
14. I can usually give good answers to test questions on science topics.	57% (8)	7% (1)	36% (5)	33% (6)	33% (6)	33% (6)
15. I learn science topics quickly.	56%(9)	25% (4)	19% (3)	50% (9)	17% (3)	33% (6)
16. Science topics are easy for me.	31%(5)	44% (7)	25% (4)	33% (6)	28% (5)	39% (7)
17. When I am being taught science, I can understand the concepts very well.	56%(9)	38% (6)	6% (1)	39% (7)	33% (6)	28 % (5)
18. I can easily understand new ideas in science.	56% (9)	31% (5)	13% (2)	39% (7)	28% (5)	33% (6)

The teacher went further, acknowledging the student, noting that it was 'actually fun'. Thus, a student who comes from a marginalised ethnic group and who 'can't read and write' was able to express her interest in hands-on non-formal science activity:

> So I think that was a huge positive cuz it is very hard to engage an L2LP learner within a group of 23 that aren't. [...] And I asked her afterwards, like I said, 'God, you worked brilliantly the other day' [here the teacher imitates the student's answer] 'Yeah, that's cuz it is actually fun' [...] I think that's massive, that student does not partake at all and isn't able to partake. Can't follow written instructions, so the fact that she was doing it with her hands–active learning and doing her own thing, and she was mad to get going, mad to do it, that was huge.

Table 4
Results of survey instrument items on 'situational interest.'

Situational interest (Chen et al., 2001)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)
		Post-test, *n* = 18	
29. The lesson in today's science class was interesting.	83% (15)	6% (1)	11% (2)
30. Dealing with the subject matter was challenging today.	39% (7)	28% (5)	33% (6)
31. I was focused on this lesson.	78%(14)	11% (2)	11% (2)
32. I enjoyed science lessons today.	78%(14)	5% (1)	17% (3)
33. Today, I understood well what we learned in class.	61%(11)	28% (5)	11% (2)
34. Today's class was fun for me.	78 % (14)	11% (2)	11% (2)
35. There was a lot going on at today's class, it was varied.	72% (13)	22% (4)	6% (1)
36. I was attentive in today's class, from the beginning to the end.	78% (14)	11% (2)	11% (2)
37. Today's material in the class attracted me, so I participated.	72% (13)	11% (2)	17% (3)
38. I want to delve into the details of the material we discussed in today's class.	78% (13)	11% (2)	11% (2)

This interpretation of the teacher is bolstered by the exit card survey, as codes such as 'fun' ', hands-on' and 'group work' appeared, which evidences the students being able to engage with the content without having to be solely reliant on written instructions. This appears to have led to a more emotional/affective engagement with the content in some instances. Further, terms associated with the practice of being a scientist, such as teamwork and group work, measuring, handling equipment, and experimental tasks (mixing, making, observing, planning, or pouring), regularly appeared. The opportunity to draw their answers was heavily utilised by the students, and the theme of 'abstract drawing' emerged alongside 'technical and labelled drawing.'[12]

When we consider this data along with the teacher interview, which, as noted previously, highlighted the autonomy an illiterate student gained with the DiSSI approaches and the data from the exit cards, a more nuanced impression emerges. As already noted, the affective domain comes through with students noting feelings of satisfaction, success, winning, fun, and enjoyment. These give a strong impression of motivating factors. The data on motivation from the survey instrument is not presented here (see Appendix) as the students struggled with the item statements in the pre-test, and as such, changes were made in the supports students were given with the instrument in the post-test and in the subsequent main study beyond this pilot.

Finally, situational interest was only examined in the post-test (Table 4), and this was found to be high, which aligns with the teacher's impression and other data from the exit cards. More specifically, items 29, 37 and 38 had a highly positive response, indicating that the students' interest in the material was linked to their engagement in the class.

Discussion

A. What are the impacts of the interventions on participants (both the students and the teachers)?
B. What kinds of new practices (or variations on the existing ones) can one introduce to best target the science capital of students during non-formal and informal pedagogical activities?

Research Question A in Section 2.5 explored: 'What are the impacts of the interventions on participants (both the students and the teachers)?' The results give a broad sense that the overall impacts of the programme have been positive for participants. The overarching goal of this programme was to determine

12 With 'abstract drawing,' we mean any drawing that goes beyond a direct representation of the activity. The drawing presents an idea that the students relate to the activity in an abstract manner and thus shows that the hands-on practical work can be theoretically contextualised by the students.

whether DiSSI-informed pedagogical approaches could work in situations where multiple dimensions of diversity were present. This was true for the context of this study, with issues ranging from socio-economic deprivation to language and literacy issues to cultural and ethnic dimensions. Thus, there was a complex interplay of diversity, yet approaches such as inquiry-based science education, elements of argumentation, Nature of Science focus, and authentic, real-life contextualisation all aided in raising situational interest and elements of the students' science capital and science identity. As discussed in earlier sections of this paper, both science identity and science capital are multi-faceted in and of themselves (Barton et al., 2013; DeWitt et al., 2016; Avraamidou, 2020). This leads to research Question B, which asked: 'What kinds of new practices (or variations on the existing ones) can one introduce to best target the science capital of students during non-formal and informal pedagogical activities?'

As acknowledged above, the interplay of pedagogical approaches utilised in this study aided in targeting elements of science capital during non-formal activities. No one pedagogical approach was utilised over another, drawing from appropriate elements of those discussed earlier depending on the topic being taught and the objectives and outcomes for the topic. It is worth noting that the pre-and post-survey results noted only modest increases in career aspiration but strong situational interest. Furthermore, there was a modest decrease in self-concept towards science between the pre-and post-survey, which must be acknowledged. The teacher interview indicates that the pedagogies employed in the DiSSI programme were outside the typical 'norms' for their classroom, as they offered the students more autonomy, a greater voice in discussing and debating the work, and more 'hands-on' practical experience with experimental work. This may have been challenging for students, as they may find this 'non-normal' to be an unfamiliar form of science learning. The challenges of hands-on inquiry-based approaches have been well noted in the literature, in line with our findings (Sharpe & Abrahams, 2020; Snětinová, 2018; Zhang, 2016). We hypothesise that the further these pedagogical approaches became normalised for the pupils, the more increases in 'self-concept' would be observed, as the data from the teacher interview and the exit cards highlight greater levels of empowerment. The data demonstrate that this was a novel exercise for many of the students since some of them felt like scientists for what was seemingly the first time. The authors believe that this potentially resulted in the slight lowering of 'self-concept towards science'. School science and non-formal science are seen as different, and this idea is manifested in the teacher interview on multiple occasions. The freedom that the students were given during this programme was new for students and classroom teachers alike. It was challenging and outside the typical comfort zone for both, yet both teachers and students indicated that they had experienced a shift and appreciated the approaches within the programme. The active learning and experimental tasks were the drivers of unique forays into the world of science. Mentions of hands-on activities were commonplace, along with references to the affective domain (evidence of emotional engagement). Again, this is in the context of the dominant cultural, community, and societal norms under which the school operates (Kenny et al., 2020; Smyth, 2020). Therefore, the richer data from the teacher interviews and exit cards aid us in concluding that the pedagogical approaches and overall impact of this study have aided in breaking down barriers to science (cf. DeWitt et al. 2016; Godec et al. 2017).

This has manifested in a number of ways. The six workshops formed a continuum, and while diverse in their design and approach, they are grounded in the key concept of an 'ask'. Students are asked to perform an activity with varying levels of support depending on their progress. In this way, adaptability to the complex social tapestry of the classroom was embedded into the overall programme, with student autonomy being central.

Unique to the data was the lack of references to their personal lives or other areas of science. The students lacked the ability to connect the workshops to their own world or school science class. The intervention was a brand-new exploration of science. The data suggests that interventions gave them their first meaningful opportunity to connect school science with authentic, context-based science and expanded their scientific language. Students referred to all the new information they had learned, utilised new terminology and vocabulary, made technical labelled drawings of their workshop, noted the ethical and philosophical challenges they encountered and finally made unique and abstract drawings of scientific phenomena. The embedded content within workshops around the Nature of Science came to fruition and targeted the students' science identity, with some noting that they enjoyed seeing the results or something actually working. The class teacher referred to the student's parents as having an awareness of the eight-week programme while not knowing about other elements of science from the school. In her eyes, this was impactful, and we would argue that the students saw the science within the programme as belonging to them, something personal and larger than what they may see in more conventional formal school science classes.

We consider the three main outcomes of this pilot study to be as follows. First, we observed that hands-on, context-based science workshops helped the students to access technical language and language to represent authentic science behaviour (such as 'design' or 'planning'.) When working with students with low socio-economic backgrounds, this is crucial as this may contribute to remove some of the 'gatekeeping' barriers posed by scientific terminology, and scientific language in general, and build a foundation for access.

Second, we have observed an increase (albeit modest) in career aspirations. The survey instrument revealed that at the end of the workshops, the students developed a better understanding of what it meant to be a scientist. Finally, we have observed high levels of situational interest, which is revealed in the survey results, as well as the teacher's testimony and the researcher's observations. According to the teacher, when she conducted experiments with them, the group of students who attended the workshops 'were able to go off and get it done themselves'. This confirms the value of conducting non-formal work in a school setting that raises situational interest, as this gives the students the opportunity to 'improve their practical skills', as the teacher put it in the interview.

The authors are keen to reiterate the challenging environment that the students, parents, school, and community are situated in. As stated earlier in this paper, inequality is complex, multifaceted, and somewhat messy. This was reflected in practice in the non-formal environment in which we worked. There were serious barriers to engagement, literacy not the least, and this eight-week programme is not a panacea to all the issues that have been discussed in the earlier part of this paper. However, we do see indicators that are important, particularly those that ultimately break down the barriers that are set up around science and scientific work and those that aid in building science capital and identity. This type of work, which is responsive to students and teachers on a weekly cyclical basis through forming a partnership, has a place in breaking down barriers and building up diversity in science going forward.

Conclusions

The current societal realities of global immigration and climate change imply that diversity, equality, and inclusion will continue to be one of the key issues in science education. As noted above, there are many forms of diversity, including gender, socio-economic background, ethnicity, linguistic, or culture. However, these rarely exist in isolation, as intersectionality theorists remind us, and they combine in ways that may lead to forms of oppression that remain invisible for the most part. A science education pedagogy that is sensitive to challenges that stem from diversity must consider intersectionality. In this paper, we have presented a pilot study, which examined how engaging in a set of context-based authentic science workshops in a non-formal setting influences students' self-concept towards science, situational interest, and some elements of their science capital. As detailed in the paper, we argued that the concept of intersectionality can provide a robust foundation for interventions aiming to target the science identity and the science capital of the students. In our pilot study, we worked with students attending an urban post-primary school in Ireland. Most students in our study come from families with a low socio-economic background, many of whom have an immigrant or refugee status, with a language other than the language of instruction (i.e., English) being spoken at home. Thus, multiple forms of diversity exist among students, some of which pose challenges that need to be addressed.

The most important aspects of our findings can be summarised as follows: Based on the survey instrument data, we have seen that the situational interest of the students has clearly improved, yet we did not see any significant change in their overall interest in science and career aspirations; and a marginal drop in self-concept towards science has been observed. However, one should note that due to their particular socio-economic backgrounds, many students have literacy issues with minimal parental support; in other words, this is a group with very low science capital. As a result, the survey instrument with its formal register proved to be challenging for the students, and we found it of essential value to complement it with observational and interview data. Indeed, the survey data, coupled with the teacher interview, exit cards, and researcher observations, led to a more nuanced picture. We have seen that the students distinguished between school science and the hands-on practice-based 'workshop science'. The exit cards, which are completed at the end of each activity, show a more positive picture of engagement in that students appreciated the context-based science activities and their science identities were well-targeted in the workshops. Literacy issues mentioned in the teacher interview are also attested by the researcher in their interactions with the students, resulting in a certain unwillingness in students to express themselves in writing or engaging with the survey instrument. Paradoxically enough, this is a group that needs intervention the most and thus, accurate measurement is essential for progress. Thus, when working with student groups whose identities are marked by intersectionality, which results in marginalisation, it is crucial to multiply modes of measurement by employing a mixed-methods approach. The problem of linking formal and non-formal learning in science education has been acknowledged in the literature (Hofstein & Rosenfeld, 1996; Rennie, 2007; Garner et al., 2014). Our findings indicate that specific challenges exist in bridging the gap between school science and non-formal context-based activities that aim to make the former accessible for students with low socio-economic and immigrant backgrounds. In particular, we note that engaging in non-formal hands-on activities does not automatically imply an increase in science interest and self-conception of science, as the students may compartmentalise school science and non-formal science. Future studies should examine what types of interventions may be effectively implemented in this context to enable students to form a more unified conception. The findings also indicate that considerations in the nature of science constitute a valuable resource for relating science to the real-life experiences of students. Further research should examine in more detail whether and to what extent the nature of science considerations can be useful in augmenting the science capital and science interest of students from diverse backgrounds.

There are several limitations of our study. As this is a pilot study, our statistical sample is not very large, and thus, our inferences must be interpreted with caution. We also need to acknowledge the literacy issues that were observed in the group as a limitation that may have affected the measurements. We began our study with the expectation of decreased levels of literacy; however, this factor has been compounded by the Covid-19 pandemic. As the teacher also attested, the pre-Covid and post-Covid disadvantages are different, given that with this group of students, the resources of the parents are limited. This limitation was addressed by taking a mixed-methods approach, combining several pieces of evidence, and providing language support to the students while they filled out the survey instrument. A further limitation of the study was our singular focus on one school, which is an urban school with an all-female student body. To address the issues of intersectionality more appropriately, we plan to extend our work to include both all-male intake and co-educational schools. Furthermore, a sizeable population in Ireland lives in rural areas. Thus, rural area schools should also be included to create a more general picture. Finally, a significant limitation of this study is that an intervention that aims at a major change in science interest and science capital has to be long-term. A long-term approach was indeed intended at the beginning of the project, yet because of the Covid-19 pandemic, this plan was not sustainable, as Ireland had one of the longest lock-down periods in Europe (Chzhen, 2022.) To alleviate this, we have conducted a series of workshops extended over several weeks that enabled a more sustained relationship with the school and the students. In future research, we plan to extend our workshops towards building a longitudinal programme that would provide more robust results concerning change in science interest and science capital.

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Appendix: Data Tables

Table 5

Results of survey instrument items on "interest in science".

Interest in science (OECD/PISA, 2009)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)
	Pre-test, *n* = 16			Post-test, *n* = 18		
1. I generally have fun when I am learning science topics.	94% (15)	5% (1)	0	61% (11)	28% (5)	11% (2)
2. I like reading about science.	81% (13)	0	18% (3)	56% (10)	11% (2)	33% (6)
3. I am happy doing science problems.	69%(11)	25% (4)	6% (1)	28% (5)	44% (8)	28% (4)
4. I enjoy acquiring new knowledge in science.	75%(12)	19% (3)	6% (1)	61% (11)	17% (3)	22% (4)
5. I am interested in learning about science.	94%(15)	0	6% (1)	50% (9)	28% (5)	22 % (4)
16. Science topics are easy for me.	31% (5)	44% (7)	25% (4)	34% (7)	28% (5)	38% (6)

Table 6

Results of survey instrument items on "motivation."

Motivation (Ryan & Deci, 2000)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree % (n)	Strongly agree & agree % (n)	Neither agree nor disagree % (n)	Strongly disagree & disagree% (n)
	Pre-test, n = 16			Post-test, n = 18		
I participate actively in science class ...						
19. ... because I feel like its a good way to improve my understanding of the material.	75% (12)	25% (4)	0	56% (10)	16% (3)	28% (5)
20. ... because others might think badly of me if I didn't.		12 % (2) 25%(4) 63% (10)			29% (5) 18% (3) 53% (9)	
21. ... because a solid understanding of science is important to my intellectual growth.	75% (12)	19% (3)	6% (1)	59% (10)	0	41% (7)
I am likely to follow my instructor's suggestions for studying science ...						
22. ... because I would get a bad grade if I didn't do what she suggests.	63% (10)	25 % (4)	12% (2)	59% (10)	18% (3)	23% (4)
23. ... because I am worried that I am not going to perform well in the course.	56% (9)	13% (2)	31% (5)	47% (8)	41% (7)	12% (2)
24. ... because its easier to follow her suggestions than come up with my own study strategies.	62% (10)	19% (3)	19% (3)	67% (12)	22% (4)	11% (2)
25. ... because she seems to have insight about how best to learn the material.	94% (15)	6% (1)	0	76 % (13)	12% (2)	12% (2)
The reason that I work to expand my knowledge of science is ...						
26. ... because it's interesting to learn more about the nature of science.	94% (15)	0	6% (1)	78% (14)	11% (2)	11% (2)
27. ... because it's a challenge to really understand how to answer science questions.	50% (8)	38% (6)	12% (2)	59% (10)	29% (5)	12% (2)
28. ... because I want others to see that I am intelligent when discussing science topics.	38% (6)	25% (4)	38% (6)	41% (7)	41% (7)	18% (3)

Biographical note

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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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Teaching Stereochemistry with Multimedia and Hands-On Models: The Relationship between Students' Scientific Reasoning Skills and The Effectiveness of Model Type

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This paper presents an analysis of the use of multimedia and hands-on models on university students' understanding of stereochemistry. The relationship between students' scientific reasoning skills and their understanding of stereochemistry was also determined. Two groups of second-year chemistry students from the State University of Malang taking organic chemistry for the 2020/21 academic year participated in this study. One group of students experienced stereochemistry teaching using multimedia models and the other hands-on models as the learning medium. Lawson's Classroom Test of Scientific Reasoning and Short-Answer Stereochemistry Test were applied. The former was deployed to measure students' scientific reasoning skills, while the latter was used to test their understanding of stereochemistry. The results revealed that the students' scientific reasoning skills were significantly below the expected standard, falling in the low category. Students with high scientific reasoning skills exhibited a better understanding of stereochemistry than those with low levels. Both multimedia and hands-on models revealed an equal contribution towards students' understanding of stereochemistry. Also, it suggests that multimedia models tend to favour students with high scientific reasoning skills, while hands-on models favour those with low skills.

Keywords: stereochemistry, pictorial representation, physical model, models, and modelling

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Poučevanje stereokemije z multimedijo in s praktičnimi modeli: odnos med zmožnostmi naravoslovnega mišljenja pri študentih in učinkovitostjo vrste modela

Rooserina Kusumaningdyah, Iztok Devetak, Yudhi Utomo, Effendy Effendy, Daratu Putri in Habiddin Habiddin

Članek predstavlja analizo uporabe multimedijskih in praktičnih modelov pri razumevanju stereokemije pri univerzitetnih študentih. Ugotovljena je bila tudi povezava med zmožnostmi naravoslovnega mišljenja študentov in njihovim razumevanjem stereokemije. V tej študiji sta sodelovali dve skupini študentov drugega letnika kemije z državne univerze v Malangu, ki so bili v študijskem letu 2020/21 študentje predmeta organska kemija. Ena skupina študentov je izkusila poučevanje stereokemije z uporabo multimedijskih modelov kot učnega medija, druga pa praktičnih modelov kot učnega medija. Uporabljena sta bila Lawsonov test naravoslovnega mišljenja za uporabo v razredu in test iz stereokemije s kratkimi odgovori. Prvi je bil uporabljen za merjenje zmožnosti naravoslovnega mišljenja, drugi pa za preverjanje razumevanja stereokemije pri študentih. Rezultati so pokazali, da je bila stopnja zmožnosti naravoslovnega mišljenja študentov precej pod pričakovanim standardom in se uvršča v nižjo kategorijo. Študentje z višjo stopnjo zmožnosti so pokazali boljše razumevanje stereokemije kot učenci z nižjimi stopnjami zmožnosti. Multimedijski in praktični modeli so enako prispevali k razumevanju stereokemije pri študentih. Študija prav tako kaže, da so multimedijski modeli primernejši za študente z visokimi stopnjami zmožnosti naravoslovnega mišljenja, medtem ko so praktični modeli primernejši za študente z nižjimi stopnjami zmožnosti naravoslovnega mišljenja.

Ključne besede: stereokemija, slikovna predstavitev, fizični model, modeli, modeliranje

Introduction

Stereochemistry involves geometric isomerism, molecular conformation, and chirality. It is fundamental to an understanding of organic chemistry and plays an important role in other disciplines, including pharmacy, biochemistry, molecular biology, biotechnology, and medicine. For example, many drugs are chiral, with only one enantiomer providing the desired effect; in some cases, the other form is detrimental. Molecular chirality can also play a part in food chemistry, where different enantiomers may impart a different taste or smell (Solomons et al., 2017). Chirality is also important in the field of heterogeneous catalysis, especially on surfaces. Therefore, understanding stereochemistry is essential for undergraduate chemistry students. Regardless of the importance of this topic, its appreciation is challenging for university students because chemistry textbooks are mostly presented in two-dimensional (2-D) representations (Abraham et al., 2010). Drawing and visualising molecules in fixed orientations and identifying the stereochemistry of those molecules is a difficult task for many students (Dickenson et al., 2020). A study involving prospective chemistry teachers revealed some misconceptions in the area of stereochemistry (Durmaz, 2018). Using three-dimensional (3D) molecular structures as building blocks for the understanding of stereochemistry is a spatial challenge for many students (Stull et al., 2012; Wu & Shah, 2004).

Efforts to improve students' understanding of stereochemistry can be carried out in several ways, including using models and modelling involving hands-on/physical models or molecular modelling. Teaching with the aid of multimedia in which pictorial and verbal representations are presented simultaneously (Mayer, 2008; Richter et al., 2016) color coding in static or dynamic forms (Mayer, 2008) has been a preferable learning approach over the years (Çeken & Taşkın, 2022). Multimedia learning contributes to cognitive development according to the following brief process. Multimedia contains words and/or pictures that are interpreted by students' sensory memory. The memory works to further process and organise the verbal and pictorial representations. Next, students store it in their long-term memory by combining the pictures and words with their prior knowledge (Mayer, 2008). However, Çeken & Taşkın (2022) found that multimedia was mostly implemented in the area of STEM education and suggested employing multimedia in other learning environments. Fatemah et al. (2020) applied mobile software and virtual tools to narrow the performance gap between students with different spatial abilities. Previous studies strongly recommended employing computational modelling to improve students' understanding of stereochemistry (Durmaz, 2018). The virtual model provides a better opportunity to manipulate the 3D models and translate 2D to 3D representations (O'Brien, 2016).

Molecular models utilising 3D have been extensively applied in some stereochemistry teaching (Upton, 2001) and other chemical molecule modelling classes (Bernard & Mendez, 2020). Using appropriate visualisation tools, the 3D models can be altered to enable the selection of pertinent viewpoints. It is possible to write line diagrams directly on top of these 3D models with the help of an overlay annotation tool (O'Brien, 2016). The study by Bernard & Mendez (2020) uncovered another advantage of 3D models over their 2D counterparts. The 3D model allowed students to create a personalised model. Another study utilised 3D printing to create a 2D model of NMR spectra and HPLC chromatograms to assist students' understanding (Jones et al., 2021). These novel physical models aid students in grasping the complicated information offered in multidimensional spectra and chromatograms, especially those who learn best through visual and/or tactile means (Jones et al., 2021). However, the unfamiliarity of students with the modelling tool is sometimes an issue (Upton, 2001), particularly in transforming 2D to 3D models (Kok, 2020). Cognitive processes of spatial visualisation have been linked to the ability to create 3D pictures of an item from its 2D views, as confirmed by research by Kösa & Karakuş (2018) and Rodriguez & Rodriguez (2017). In addition, It is difficult to model even tiny molecules with any degree of accuracy using 2D drawing software, let alone 3D (Bernard & Mendez, 2020).

Comparisons of the effectiveness of the two models (virtual and hands-on) towards students' understanding of stereochemistry are limited (Casselman et al., 2021). Several studies utilised 3D printing (Dickenson et al., 2020), hands-on laboratory work (Taagepera et al., 2011), multimedia technology (Ugliarolo & Muscia, 2012), interactive computer games (Júnior et al., 2017) and stereochemistry physical games in the form of a boardgame (Júnior et al., 2019) to assist students in understanding stereochemistry concepts. However, they did not compare the effectiveness of the two selected tools. For example, Dickenson et al. (2020) conducted a 3D printing workshop to improve students' fluency in drawing stereochemistry structures and other related entities (chirality, stereoisomerism, enantiomer, diastereomers) and their understanding was measured before and after the workshop. Thayban et al. (2021) compared hands-on and virtual models in the teaching of symmetry. Casselman et al. (2021) contrasted the effects of teaching organic chemistry with virtual versus physical Embodied Learning Tools (ELTs) on students' understanding of stereochemistry. Web-based tools with virtual-3D have also been applied to assist students in transforming Newman projections (the conformation of the chair and assigning R/S labels) to a

2D dashed/wedged structure (Mistry et al., 2020). Elford et al. (2022) and Habig (2020)first representations are examined from a science educational and instructional psychology perspective. After giving a short overview of AR in general and how it can be delineated from virtual reality (VR employed augmented reality (AR) to provide a 3D virtual environment for teaching stereochemistry. Another study incorporated animation and hands-on models to improve students' understanding of organic chemistry (Al-Balushi & Al-Hajri, 2014). The use of multimedia is expected to assist students in visualising chemistry concepts (Rodrigues & Gvozdenko, 2011) Abraham et al. (2010) applied computer modelling and a handheld ball-and-stick model to assist students' understanding of stereochemistry. Although this study compared computer and hands-on models, it did not relate to students' scientific reasoning skills (SRS).

SRS and critical thinking are the core competencies that students must harbour for their future careers (Dowd et al., 2018)but little empirical evidence exists regarding the interrelationships between these constructs. Writing effectively fosters students? development of these constructs, and it offers a unique window into studying how they relate. In this study of undergraduate thesis writing in biology at two universities, we examine how scientific reasoning exhibited in writing (assessed using the Biology Thesis Assessment Protocol. SRS correlate with students' ability to carry out observations, investigations, and modelling (Bunce et al., 2017; Krell et al., 2020). Referring to Piaget's theory, SRS is related to the last development of the cognitive stage, which is formal operational (Babakr et al., 2019). The development of students' SRS correlated to cognitive and emotional involvement in augmented reality-based instruction (Chang et al., 2018). Students' ability to predict and explain chemical phenomena is affected by their understanding of chemical as well as mathematical modelling (Lazenby et al., 2019). According to Lawson, scientific reasoning plays a central role in producing scientific knowledge (Bao et al., 2022). Stereochemistry concepts (chirality, enantiomer, and symmetry) are mostly represented by models to assist students in better understanding them. Therefore, efforts to reveal the relationship between students' SRS and their understanding of stereochemistry deserve attention.

Models and Modelling in Science and Chemistry Education

According to The Oxford English Dictionary, a model refers to a three-dimensional representation of a smaller object scale'. The use of the term 'model' can be expressed as the simplification of natural phenomena (e.g., an idea, system, situation, or process) and used as the basis for explaining and understanding them (Bodner et al., 2005; Gilbert, 1997; Hallström & Schönborn, 2019); therefore, it facilitates scientific inquiry (Ingham & Gilbert, 1991). Chamizo (2013) reviewed and proposed various definitions of models and finally agreed with the previous definition that a model represents entities (ideas, phenomena, objects, processes, and systems) connecting theory and phenomena. A model can also be presented in a mathematical expression, such as the relationship of volume, temperature, and the number of gas molecules in gas laws (Bodner et al., 2005). At the same time, modelling refers to constructing a model for a particular system (Bodner et al., 2005) that serves as a thinking and communicative tool for predicting, explaining, and communicating scientific phenomena (Chamizo, 2013).

It has been widely accepted that chemical concepts are mostly explained in the sub-microscopic and symbolic models due to their abstract characteristics. Therefore, in chemistry, we deal with several phenomena interpreted and communicated through certain models (Justi & Gilbert, 2003). Dalton's atomic model has been the pioneer for how the physical model contributes to the progress of chemical knowledge, followed by other chemists' findings, including Kekulé, Van't Hoff, Pauling, Watson and Crick (Justi & Gilbert, 2003). Using a molecular model facilitates the prediction of chemical behaviour and structural and spatial arrangement, particularly in topics such as stereochemistry (Francoeur, 1997, 2000).

Understanding modelling in chemistry teaching and learning is essential for chemistry educators to recognise the most appropriate model to apply in their teaching (Sjöström et al., 2020). Chemistry educators are expected to understand the nature of the model, construct an appropriate model, utilise the model in chemistry teaching and conduct modelling activities in their teaching (Justi & Gilbert, 2003). In another study, Savec et al. (2006) investigated both prospective and in-service chemistry educators' opinions regarding the role of models and modelling in chemistry and revealed that they were acutely aware of its importance. In line with the increasing deployment of new technologies, such as visualisation, animation, and other computer simulations in the educational sector, the technological literacy of teachers and educators has also increased (Ferk et al., 2003).

Studies involving the use of models and modelling in chemistry have been carried out on many topics, including solid-state of matter (Devetak et al., 2010), revealing students interacted with their own-physical model superior to those with the virtual model and teacher-demonstrated physical model. Regarding retention, students remembered the theory when they had constructed their own either physical or virtual models rather than using teacher-demonstrated ones. Fried et al. (2019) also revealed an improvement in students' motivation and understanding of chemistry when they used student-generated models in organic chemistry and computer-generated models in teaching. The combination of practical work and computer modelling also improved students' performances in crystallography (Daaif et al., 2019). Beck et al. (2020) investigated how students apply models to understand molecular vibrations and rotations of molecules. In other studies, laboratory modelling by asking students to draw the decay of radioactive elements effectively uncovered their misconceptions of radioactive decay and half-lives (Yeşiloğlu, 2019). These studies confirm that models and modelling are useful tools for improving students' understanding and revealing misconceptions.

Students' comprehension of models and modelling (Justi & Gilbert, 2003) is the key aspect of the next standard of science (Guy-Gaytán et al., 2019). Chemistry students frequently use existing models in many topics, including gas laws, the kinetic theory, the theory of collision, the steric effect and others, but they do not directly involve in constructing and evaluating a model (Bodner et al., 2005). Considering this, we provide ample opportunities for students to be actively involved in modelling the stereochemistry concepts.

Research problem and question

Providing appropriate learning tools for teaching stereochemistry has been a priority for some time; however, despite this, many students still find the topic challenging. The main objective of this study was to examine the effect of multimedia and hands-on models on students' understanding of stereochemistry. In addition, the relationship between students' understanding and scientific reasoning skills was explored. The result of this study could be the basis for finding the optimum learning medium for teaching stereochemistry.

Method

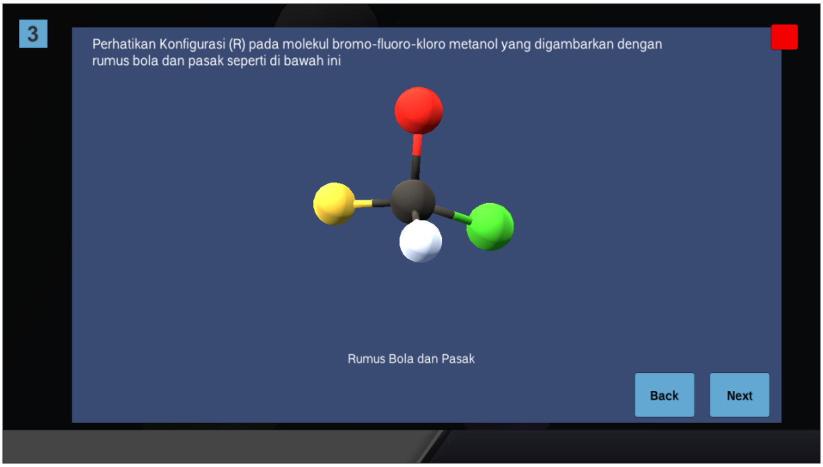
Pre-tests and post-tests were implemented for each intervention in this study, with two separate groups of students. One group used hands-on models (comparison group), and the other used multimedia models (experimental group) in teaching and learning stereochemistry. In some literature (Casselman et al., 2021), hands-on models are named 'physical models'. Therefore, the terms 'hands-on' and 'physical' are used interchangeably in this paper.

Participants

This study involved 59 second-year chemistry education students from Universitas Negeri Malang taking the Organic Chemistry I class. The students were, on average, 22 years old (*SD* = 2.0). They all learned chemistry in secondary school for three years, covering general and organic chemistry concepts. They also covered concepts helping to understand stereochemistry, such as chemical bonding, molecular geometry, and fundamental concepts in organic chemistry, specifically nomenclature, structure, and reaction mechanisms. The students were divided into two groups, with 29 students for the multimedia-models group and 30 for the hands-on model group. From this point and beyond, students experiencing stereochemistry teaching with a multimedia model are labelled STwM, while those using the hands-on model are labelled STwC.

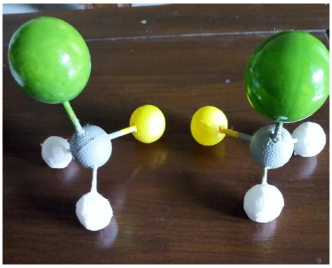
Examples of multimedia and hands-on models are provided in Figures 1 and 2. The multimedia model displayed in Figure 1 was created in a computer program using Unity3D and Blender software. The model can display a three-dimensional representation of the molecules.

Figure 1
Example of the multimedia model in this study (translation provided)



The English translation for the question in Figure 1 is 'look at the (R) configuration of bromochlorofluoromethane that is displayed as a ball and stick model below'. (*Rumus Bola dan pasak* means ball and stick model). Figure 1 displays the R configuration of bromochlorofluoromethane CHBrClF as a ball and stick model. The 3-D model allowed students to physically manipulate the object to view the different arrangements. As shown in Figure 2, the hands-on 3D model is formed from a plastic ball and straws created by students.

Figure 2
Example of the hands-on model in this study



Research Design

This study employed a pre-test-post-test two-treatment design (Cohen et al., 2018). Before embarking on stereochemistry teaching, students' SRS ability was analysed using the CTSR instrument. Students' responses were the basis for classifying them as having a high or low level of SRS. Students in both classes (STwM and STwC) were divided into groups and labelled as students with high and low SRS (Table 1).

Table 1
Pretest-posttest two treatment design of the study

SRS level	Multimedia class (STwM)	Hands-on model class (STwC)
High	X_{111}	X_{121}
Low	X_{112}	X_{122}

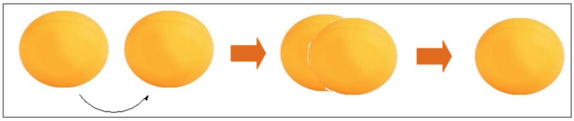
X_{111} and X_{112} were labelled for STwM students with high SRS and low SRS levels, respectively, while X_{121} and X_{122} were for high and low SRS levels among STwC students. The labels are only applied for research purposes to be more recognisable when analysing the data. Both high and low SRS levels were mixed in stereochemistry teaching and experienced the same learning environment based on applied learning media. The teaching approach for STwM and STwC classes was the same (guided discovery model), except for the learning media. The steps of guided discovery in this study adopted the model proposed by Eggen & Kauchak (2012) as follows.

1. Introduction phase

In this phase, the concepts to be discussed are related to previously studied concepts. For example, when discussing 'chirality and enantiomer', students were reminded of structural and geometric isomerism. Then, students were given an analogy question to introduce students to the subsequent topic. Below is the typical question provided in this phase. *Figure 3 below portrays two mirrorable spherics. Do you think the two spherics are superimposable mirror images?*

Figure 3

Example of a mirrorable object presented in the introduction phase

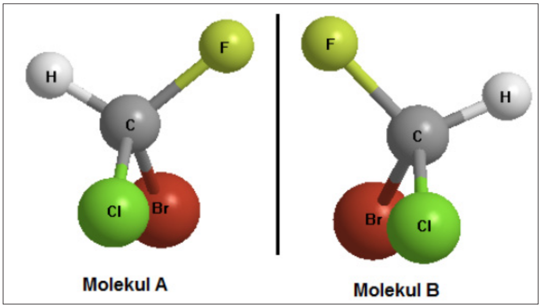


2. Open-ended question

The learning model for STwM and STwC groups was applied in this phase. Students were asked to think and express their opinion regarding the follow-up questions. *Figure 4 below is an example of a question provided in this phase. Do you think that the B molecule (molekul B) mirrors the A molecule (molekul A)? Are the two molecules superimposable?*

Figure 4

Example of the mirrorable object presented in the open-ended phase



Students then explored the possible answer to the question using the assigned teaching materials, including the learning media. STwM applied the multimedia model, while the STwC did so with the hands-on model.

3. Convergent phase

In this phase, the lecturer explained the correct answer for the questions given in the previous phase, correcting any misunderstandings that occurred and providing any other necessary explanations of the topics.

4. Closure and application phase

In this phase, some additional questions were given to assess the extent to which students understood the topic.

Instruments and Data Analysis

Data in this study cover students' scientific reasoning skills, initial ability, and understanding of stereochemistry after the intervention. Students' scientific reasoning skills (SRS) in the two groups were measured and categorised as those with higher scientific reasoning skills and those with lower scientific reasoning. Students' scientific reasoning skill was measured using the Classroom Test of Scientific Reasoning (CTSR) developed by Lawson (1978), consisting of 24 multiple-choice questions. Following the criteria of Lawson (2004) thus arguments used in their test require sub-arguments to link the postulate under test with its deduced consequence. Science is HD in nature because this is how the brain spontaneously processes information whether it basic visual recognition, every-day descriptive and causal hypothesis testing, or advanced theory testing. The key point in terms of complex HD arguments is that if sufficient chunking of concepts and/or reasoning sub-patterns have not occurred, then one's attempt to construct and maintain such arguments in working memory and use them to draw conclusions and construct concepts will "fall apart." Thus, the conclusions and concepts will be "lost." Consequently, teachers must know what students bring with them in terms of their stages of intellectual development (i.e., preoperational, concrete, formal, or post-formal, students' SRS was categorised as preoperational (0–9 correct answers), concrete (10–14 correct answers), formal (15–19 correct answers), or post-formal (20–24 correct answers). Students with preoperational and concrete levels are attributed to lower SRS, while those with formal and post-formal levels are higher SRS.

Students' understanding of stereochemistry was revealed using ten short answer questions (SAST). Examples of questions from the two instruments are displayed in Figures 5 and 6, while the complete instruments are available on request. Pre-test and post-test questions were used to investigate students' understanding of stereochemistry in the two groups. However, students' scientific reasoning was measured only in the pre-test.

Figure 5

Example of a question of the CSTR instrument

The six boxes are placed in a wrapped container and mixed randomly. If one box is taken out from the container, what is the percentage possibility that a red box was taken?

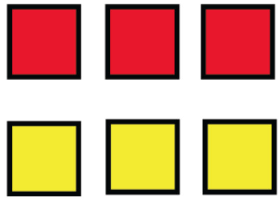
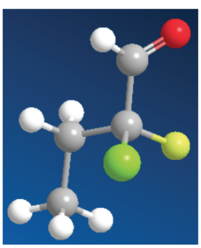


Figure 5 above depicts the example of a question in the CSTR instrument to measure students' scientific reasoning skills. This question is followed by another question asking the reason for their answer. Meanwhile, Figure 6 displays an example of a question of the SAST instrument to measure students' understanding of stereochemistry. The question is in the Indonesian language but is provided in English on this page for international readers. As mentioned above, the complete instruments are available on request.

Figure 6

Example of a question about the SAST instrument



The figure is the structure of 2-chloro-2-fluorobutanal (red sphere represents O atom, grey for C, white for H, green for Cl and yellow for F atoms.

a. Arrange the priority order of the subtituents attached to C-chiral starting with the highest priority.
b. Draw the three-dimensional formula of the enantiomer pair for the molecule.
c. Provide the sign of (R) or (S) to the two enantiomers and their names.
d. Do you think the two molecules are the same? Explain your answer

Non-parametric statistical procedures, including Rank-Spearman Correlation and the Mann-Whitney U test, were employed to measure the correlation between students' SRS and understanding of stereochemistry and the difference between the two groups. Prerequisite tests were applied, including Levene's Test for homogeneity and the Shapiro-Wilk for normality test. The results showed that the data were not normally distributed and not homogenous, leading to the use of the non-parametric procedure above.

Results and Discussion

The Students' Scientific Reasoning Skills (SRS)

The results of Students' Scientific Reasoning Skills measurements (SRS) are provided in Table 2.

Table 2

Students' SRS Scores

Score	Number of Students	%	SRS Level
0–9	16	29.63	Concrete
10–14	19	35.18	Low Formal
15–19	11	20.37	Upper Formal
20–24	8	14.81	Post Formal

The results indicate that the smallest percentage of students (14.81%) possess the highest SRS level, *post-formal.* Students with *low formal* and *concrete* SRS levels are the highest in number, with 35.18% and 29.63%, respectively. These percentages imply that the majority of second-year chemistry students hold inadequate SRS levels. This confirms the previous finding that most promising science teachers demonstrate a low SRS (Zulkipli et al., 2020). Piaget's theory states that people develop their highest stage of cognitive development, the formal operational stage, at the age of 11 (Babakr et al., 2019). However, Lazonder et al. (2021) found that the level of scientific reasoning of people of the same ages could develop differently. Even some adult people have not reached this formal reasoning stage (Martin et al., 2010). These students' low scientific reasoning skills should be taken into account in further chemistry teaching. Studies involving university students from the first to fourth years revealed a small correlation between university experiences (how many years they have been in university) to students' SRS (Ding et al., 2016). This paper will only describe how these SRS categories relate to students' understanding of stereochemistry between the STwM and STwC classes. *Concrete* and *low formal* levels are both considered as the low SRS category, while *upper formal* and *post formal* are the high SRS category.

Students' initial ability and the use of multimedia and hands-on models in stereochemistry teaching

The effect of teaching stereochemistry using multimedia and hands-on models is demonstrated by the difference in average scores between the STwM and STwC classes. Table 3 outlines the average marks of the two classes for the pre-test and post-test exercises.

Table 3

The average scores (out of 100) of STwM and STwC classes in SAST before and after the course in stereochemistry using different molecular models

Class	Number of Students	Score for pre-test		Score for post-test	
		X	*SD*	*X*	*SD*
STwM	27	8.2	5.4	58.9	17.4
STwC	27	9.8	7.4	54.9	9.2

The table shows that students' marks for the pre-test are much lower than for the post-test, which is understandable because the pre-test was carried out before the teaching of stereochemistry to the two classes. Students' prior knowledge of stereochemistry is mainly obtained from their secondary school chemistry lessons and is very basic. In this university, fundamental organic chemistry concepts are not covered in basic or general chemistry. The correct answers were mostly found for questions about isomeric structures and cis- and trans-geometric isomerism. They mostly failed to answer questions regarding optical isomers, molecular chirality, diastereomers and mesosomers. Some students also struggled to distinguish between geometric isomers in cyclic compounds and alkenes.

The pre-test aimed to determine students' initial ability in STwM and STwC classes before embarking on stereochemistry teaching. Although the STwM (8.2) mark was slightly lower than that for STwC (9.8), the difference is insignificant. Therefore, it can be concluded that both classes harboured the same level of ability and prior knowledge regarding the topic implying an acceptable interpretation that the use of multimedia and hands-on models will determine the post-test outcomes.

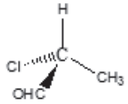
Table 2 also shows that the STwM demonstrated a higher mark average (58.9) than the STwC class (54.9). However, the difference is very small and is not statistically significant, as confirmed by the Mann-Whitney test with a *p*-value of 0.257. Therefore, it can be concluded that the use of multimedia and hands-on models in stereochemistry teaching contributed equally to supporting students' understanding. This finding is opposite to the study in the area of solid-state matter in which students who constructed their physical model (equivalent to the hands-on model in this study) demonstrated a better performance than those using virtual models (Devetak et al., 2010). Meanwhile, another study revealed that students from all educational levels demonstrated different approaches to different models. Although students mostly favour hands-on representations over virtual ones, university and secondary school students demonstrated a better performance when using the three-dimensional virtual or computer-generated models, whereas primary school students favoured physical 3D models (Ferk et al., 2003).

Students' post-test average scores for the two classes show that their understanding of stereochemistry is still weak even after deploying multimedia and hands-on models. An analysis of students' attempts to answer one specific question is given below for the example shown in Figure 7.

Figure 7

Example of the question for SAST

Look at the dimensional structure of a molecule below and answer the following questions.

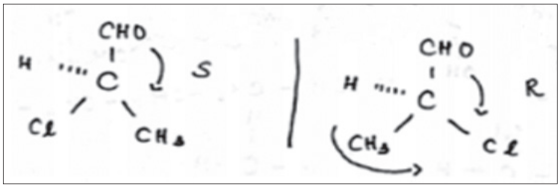


a. Mark the substituents according to the priority rules.
b. Provide the dimensional structure of the enantiomer pair for the molecule.
c. Show the (R) or (S) configuration for the two enantiomer.
d. Please provide a complete name of the molecule by considering its (R) or (S) configuration.

Figure 8 shows that many students failed to apply the priority order of the substituents as explained in the priority rules of Cahn-Ingold-Prelog. They considered CHO as the priority instead of Cl. This inability led to the students' errors in determining the R or S configuration. Additionally, students' inability to visualise a three-dimensional unit could have contributed to this error. Difficulty in determining R and S configurations was also found in previous studies (Durmaz, 2018).

Figure 8

Example of students' difficulty in determining the (R) and (S) configuration



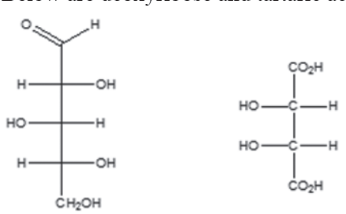
The relationship between SRS and students' understanding of stereochemistry

The relationship between students' SRS and their understanding of stereochemistry can be seen by comparing the average scores of the two groups in answering the SAST questions. For students with high SRS, the score of the stereochemistry test of STwM (76.6) is higher than that for STwC (68.9). In contrast, for those with low SRS, STwC students (62.0) performed better than the STwM students (56.3). This result also demonstrated that for both groups, students with high SRS have a better understanding of stereochemistry than those with low SRS. The result indicates that students' SRS affects their understanding of stereochemistry with a positive correlation. The Rank-Spearman Correlation test also confirmed this finding, showing a moderate correlation between these two variables (r_s = 0.383; p = 0.004). The obvious relationship between the two variables proves that the ability to think scientifically affects students' success in understanding stereochemistry.

Figure 9

Example of the question for STSA

Below are deoxyribose and tartaric acid in Fischer projection



a. How many carbon chiral at the deoxyribose compound and mark those chiral carbon?
b. How many stereoisomer at the deoxyribose compound?
c. Tartaric acid contains 2 carbon chiral but only 3 stereoisomers. Explain why.
d. Which one has the internal plane symmetry between the two? Show it in a figure.
e. What is the effect of internal plane symmetry to its optical activity?

Students with low SRS failed to deal with questions that require thinking at the formal level. Below is an example of those students' errors in explaining why a compound exhibits geometric isomerism and how the plane symmetry in a molecule with chiral carbon atoms affects its optical activity.

Figure 10

Example of students' difficulty in answering the question regarding molecules having internal-symmetry-plane

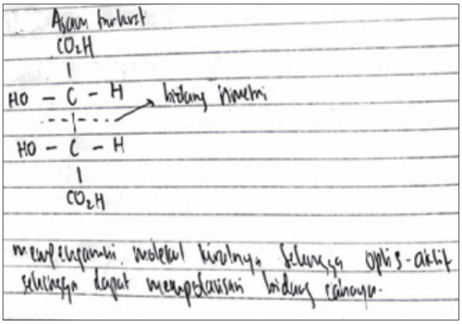


Figure 10 demonstrates students' inability to answer questions displayed in Figure 9. Some students correctly appointed the plane symmetry of tartaric acid (*asam tartarat* in the Indonesian language) but failed to recognise its effect on its optical activity. They believed that *molecules with a plane of symmetry would remain optically active,* as stated (translated from the Indonesian language) in the figure. This difficulty may also be the result of the possibility that they had trouble recognising the compound's optical activity because the tetravalence of the carbon atom did not line up with the polarity of the carboxyl groups at either end. Thus, the carbon atoms at the chain's centre could likewise be identified as chiral centres. Students with good scientific reasoning skills should explain that the existence of an internal symmetry plane divides a compound in half, with the two halves reflecting each other (mirror image). They then should realise that such a molecule with a plane of symmetry is achiral and optically inactive. Some students also struggled to determine whether the enantiomeric pairs were the same compound. Many students believed that the pairs were the same compound confirming a lack of ability to recognise the differences in the position of a molecule's group in three-dimensional space. Students often lack a clear understanding of the idea of optical activity. In the absence of a convincing classroom demonstration, pupils frequently have no choice but to take it on faith (Pecina et al., 1999). However, current technology could assist students in understanding the optical activity phenomenon.

Schwartz et al. (2011) applied an iPad device with the function of a source of polarised light for observing the optical activity of crystal or solution, including NaCl and $NaClO_3$ crystals and sucrose solution.

The Effect of Hands-on and Multimedia Models on Students' Understanding of Stereochemistry

Table 4 shows the percentage of students from each group giving the correct answer to each of the questions. The table shows that, for six questions (1, 2, 4, 5, 9 and 10), the number of STwM students providing a correct answer is greater than that of STwC students. However, the difference between the two groups is quite small. This suggests that multimedia and hands-on models are equally effective in improving students' understanding of stereochemistry, as confirmed by the small difference in scores between STwM and STwC students. The statistical test confirmed the insignificant difference between the two groups.

Both multimedia and hands-on models facilitate students in understanding stereochemistry. Multimedia helps students build mental visualisations because the features of virtual molecular models, animated videos and games allow them to observe three-dimensional molecular shapes from various points of view, allowing their rotation and other movements (Anggriawan, 2017). The mobile and virtual models effectively closed the gap in understanding of students with different spatial abilities (Fatemah et al., 2020). The result of this study is at odds with the work of Abraham et al. (2010), in which computer modelling was found to be better than the physical ball and stick models in aiding students' understanding of stereochemistry. In agreement with the work of Abraham et al. (2010), the physical model was more effective in facilitating students to apply complex stereochemistry concepts compared to the virtual one (Casselman et al., 2021). This finding also conflicts with a study on students' understanding of symmetry, which showed that virtual models favoured students' understanding over physical ones (Thayban et al., 2021). The study strengthened their review results that the contribution of the virtual model will exceed the physical model's contribution (Thayban et al., 2020).

Table 4
The percentage of STwM and STwC students with the correct answer in responding to SAST (Students' Understanding of Stereochemistry Concepts)

Question	STwM (%)	STwC (%)
1	73	72
2	55	44
3	58	61
4	71	64
5	64	47
6	42	44
7	74	79
8	45	55
9	53	40
10	50	41
Average	**58**	**55**

An interesting phenomenon is observed when the stereochemistry scores are a function of students' SRS (Table 5). For students with high SRS, STwM students demonstrated a higher score. Meanwhile, STwC students with low SRS performed better than STwM students with similar low SRS.

Table 5
Students' grade average on stereochemistry test

	SRS category	The average score of the stereochemistry test
STwM	High	66.7
	Low	49.0
STwC	High	60.0
	Low	54.0

Considering the small sample size in this study, it may sound too ambitious to claim that the multimedia model is more effective for high SRS students while the hands-on model is for low SRS students. However, further studies to explore the findings involve bigger respondents.

Conclusion

This study revealed that the difference in students' understanding between those experiencing multimedia and those with the hands-on model is quite small, as confirmed by the Mann-Whitney test's statistical procedure. The result suggests that employing both multimedia and hands-on models in teaching stereochemistry can be effective, and the specific model chosen should be determined by the teaching environment. The average post-test scores for both groups also imply that the application of the two models did not improve students' understanding to a satisfactory level. We do believe that models are the obvious tool to teach stereochemistry. Therefore, exploring why it does not work optimally in this study should be further investigated. It may be reasonable to provide an additional variable to promote a more effective stereochemistry teaching using multimedia and hands-on models. This study also uncovers that students' scientific reasoning skills influence students' understanding of stereochemistry. Regardless of the model applied, the higher students' scientific reasoning, the better their understanding. Therefore, techniques that enhance students' scientific reasoning skills should be deployed to assist their understanding of stereochemistry and other topics.

Implication for the teaching of stereochemistry

This study, and other previous reports, indicate that both hands-on and virtual models are useful in aiding students' understanding of stereochemistry. However, no specific benefit could be determined from deploying either technique. It is therefore recommended that educators select an appropriate medium dependent upon the characteristics of the students, availability of resources and other considerations. There is limited evidence from this study that students with low scientific reasoning skills may benefit from using hands-on models, as this group of students showed a higher score on the stereochemistry test than the group with the same SRS using virtual models. There appeared to be a slight benefit for students with high SRS in using multimedia models. It may be beneficial to choose the appropriate model type depending on the students' scientific reasoning skills.

Limitations of The Study and Future Research Guidelines

Students' scientific reasoning skills were measured before the stereochemistry exercise but not after. One question arising from this study is exploring how teaching using different model types affects students' scientific reasoning skills. The absence of a comparison group in this study could also hinder the transferability of the result to a wider context. Therefore, a future study employing a comparison group and involving a larger number of respondents is highly recommended, especially to determine the relationship between SRS and the effectiveness of different model types. Other variables, such as visualisation skills, motivation, and interest, are also reasonable to explore further. Other drawbacks of this study are the lack of eye tracking as a useful tool informing students' visual ability (Brumberger, 2021) and the spatial ability test as another important factor related to understanding the 3D orientation of stereochemistry. The unavailability of the eye-tracking tool is the reason for the former drawback. We also decided to skip the spatial test ability to reduce the students' workload participating in this study.

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Slovenian Language Teachers' Attitudes Towards Introducing Comics in Literature Lessons in Primary School

Maja Kerneža*[1] and Igor Saksida[2]

The present article highlights the views of Slovenian language teachers on the introduction of comics in literature lessons in primary school. We were interested in Slovenian language teachers' views on the introduction of comics as an art-literary type of text as part of the literature curriculum as well as the use of comics as a literary-didactic method in literature classes. This was investigated via a questionnaire, which was fully completed by 121 Slovenian language teachers of the first to the ninth grade. The results show that factors such as gender, educational period taught, professional experience, field of study, highest level of completed education, source of skills related to the introduction of comics in the classroom, teachers' reading habits and attitudes towards reading comics, and agreement with stereotypical claims about comics per se have no influence on teachers' attitudes towards the use of comics in the forms studied. However, their attitudes towards the use of comics in the classroom are influenced by certain stereotypical attitudes of teachers towards comics. The most important limitation of our research was also the most important finding: teachers are neither empowered to introduce and use comics as an art-literary type of text in the literary curriculum, nor are they able to use comics as a literary didactic method in literature classes. There is a great need for teacher training and teachers should be empowered to use and introduce comics in all forms.

Keywords: comics in education, literature lessons, primary school, teacher attitudes

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Stališča učiteljev slovenščine do uvajanja stripa v pouk književnosti v osnovni šoli

Maja Kerneža in Igor Saksida

Članek predstavlja stališča učiteljev slovenščine do uvajanja stripa v pouk književnosti v osnovni šoli. Zanimala so nas stališča učiteljev slovenščine do uvajanja stripa kot likovno-literarne vrste besedila v književnovzgojni kurikulum pa tudi do uporabe stripa kot (produktivne) literarnodidaktične metode pri pouku književnosti. To smo raziskali s pomočjo anketnega vprašalnika, ki ga je v celoti izpolnilo 121 učiteljev slovenščine od prvega do devetega razreda. Izsledki kažejo, da dejavniki, kot so: spol, vzgojno-izobraževalno obdobje, v katerem učitelji učijo, delovne izkušnje, smer končanega študija, najvišja stopnja dokončane izobrazbe, lokacija in velikost šole, na kateri poučujejo, vir kompetenc, ki se navezujejo na uvajanje stripa v pouk, bralne navade učiteljev in odnos do branja stripov, sami po sebi nimajo učinka na stališča učiteljev do uporabe stripa v raziskovanih oblikah pri pouku književnosti, vplivajo pa na njihova stališča do uporabe stripa pri pouku določena stereotipna stališča do stripa. Kot poglavitna omejitev raziskave se je pokazala prav najpomembnejša ugotovitev – učitelji niso opolnomočeni ne za uvajanje in uporabo stripa kot literarno-likovne vrste v književnovzgojni kurikulum in ne za uporabo stripa kot (produktivne) literarnodidaktične metode pri pouku književnosti. Kaže se velika potreba po izobraževanjih učiteljev, v okviru katerih bi se učitelje opolnomočilo za uporabo in uvajanje stripa v vseh oblikah v pouk slovenščine oz. maternega jezika.

Ključne besede: osnovna šola, pouk književnosti, stališča učiteljev, strip v izobraževanju

Introduction

Attitudes are socially acquired by adopting social knowledge, experiences and norms. We acquire attitudes throughout our lives from parents, peers and the social environment (Olson & Kendrick, 2008); we have no biological predispositions to them. By learning attitudes from others, individuals become similar to members of their group (Albarracin et al., 2018). Attitudes and beliefs also guide teachers and influence their work (Darling-Hammond, 2000) in terms of their practices (Cash et al., 2021; Süer & Oral, 2021), behaviour (Glock et al., 2018; Mellom et al., 2018), improvement of the learning process (Xu, 2012) and the learning environment (Russo et al., 2021), motivation (Kulikowski et al., 2022), language (Smajla, 2021), knowledge (Rosli et al., 2020) and skills (Leffler, 2019). Some research (e.g., Ballantine & Spade, 2006; OECD, 2009) even concludes that understanding the role of the teacher is key to understanding the education system, as teachers' views are important for the educational environment and for understanding and improving the learning process.

Comics are almost synonymous with stereotypes and attitudes. Even today, comics are still making their way into libraries and classrooms. Doubts exist especially about the criteria for selecting quality comics and the possibilities of using them in the classroom, but all too often there are still stereotypical and negative attitudes towards the use of comics in literature classes, as expressed in our previous research (Kerneža, 2016). The origin of comic stereotypes in the educational environment is presented by Groensteen (2009). The first comics were intended for adults, and were published in America in the nineteenth century. At the beginning of the twentieth century, the same comics found their way to Europe, where they were published mainly in children's and youth press. Since teachers were the first to comment on comics and the idea of comics, their views (which were anything but positive due to their being the wrong audience) prevailed over other opinions. Comics were condemned as harmful to children, supposedly spoiling an already limited audience. As a result, they are still often criticised for their lack of narrative ambition, considered entertainment and/or trivial literature and lumped into popular genres (e.g., adventure, fantasy, historical, etc. stories), even though they are essentially an original medium.

In the context of research, we are mainly interested in the use of comics in literature classes. Teachers most often use comics in literature classes as an art-literary type of text or as a literary-didactic method. We typically think of comics as literary works, but their most recognisable feature distinguishing them from other types of reading texts is the need to assemble meaning from both the text and the illustrations, which Batič and Haramija (2014) define as multimodality in the case of a picture book. Like the picture book (Batič & Lebar Kac, 2020), the comic book has at least two codes of communication: literary and artistic. It is an interweaving of text, illustrations and the content-formal relationship between them (Haramija & Batič, 2015). A study conducted among 443 preschool and classroom teachers (Batič, 2021) showed that teachers consider picture books to be suitable and appropriate for preschool and school children. Moreover, the participants did not have difficulties selecting an appropriate picture book (like picture books, comics are also a multimodal text). However, research on comics as a literary-didactic method for reducing gender differences in reading literacy at the primary level of education has shown that there are prejudices and negative attitudes among Slovenian language teachers towards the use of comics in the classroom (Kerneža, 2016). As stated above, both picture books and comics represent a similar concept of text, that is, multimodal text.

Today, more and more research demonstrates the positive effect of comics (e.g., mathematics: Azamain et al., 2020; science: Phoon et al., 2020; art: Osterer, 2012; foreign language learning: Zhang, 2019; reading comprehension: Liu, 2004; attitudes towards reading: Kerneža & Košir, 2016; transaction between literary texts: Oppolzer, 2020). Therefore, there should no longer be doubts about the effectiveness of comics as part of the curriculum.

Since students directly observe their teacher's views daily (Greene, 2006), teachers often pass on attitudes that are either positive or negative through instruction, by addressing or not addressing certain topics in the classroom (Gal et al., 1997; Lawal, 2020; Rensaa, 2019; Ugur-Erdogmus, 2021) and in the learning environment (OECD, 2009). Teachers' attitudes are frequently highly resistant to more complex changes, but they often depend on the personal characteristics of the teacher (ibid). When people talk about teachers being 'hard to move', it is usually referring to their views. However, some research shows that teachers' attitudes and practices can easily be changed if the programmes we use to influence their views are implemented with sufficient quality (Darling-Hammond, 2000; Hu, 2022). Of course, we need to know what teachers think and what they know about the issues we want to present to them. With the goal of helping teachers create more powerful learning environments, Schoenfeld (2020) even suggests that we influence their perceptions, inclinations and orientations in the field of their knowledge.

The present study

Since we did not find any research on the described topics, we designed a study based on the theoretical foundations and empirical findings. The aim of the present study was to investigate the attitudes of Slovenian language teachers in primary schools towards the introduction of comics as an art-literary type of text and the use of comics as a literary-didactic method in literature classes. We sought to investigate Slovenian language teachers' attitudes towards the most common ways of using comics in literature classes. The research questions we developed were divided into two groups for better transparency:

1 What are the attitudes of Slovenian language teachers towards the introduction of comics as an art-literary type of text in the literary curriculum?
  1. 1 Which factors influence Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum?
  1. 2 Which stereotypical attitudes do Slovenian language teachers have towards the introduction of comics as an art-literary type of text in the literary curriculum?

2 What are the attitudes of Slovenian language teachers towards the use of comics as a literary-didactic method in literature classes?
  2. 1 Which factors influence Slovenian language teachers' attitudes towards the use of comics as a literary-didactic method in literature classes?
  2. 2 Which stereotypical attitudes do Slovenian language teachers have towards the use of comics as a literary-didactic method in literature classes?

As a general hypothesis, we concluded that the attitude of Slovenian language teachers to the introduction of comics as an art-literary type of text in the literary curriculum and to the use of comics as a literary-didactic method in literature classes depends on gender, the educational period in which the teachers teach, professional experience, field of study, the highest level of education completed, the source of skills related to the introduction of comics in the classroom, teachers' reading habits, their attitudes towards reading comics, and the level of their stereotypical thoughts about comics. The use of comics in the classroom is also affected by teachers' stereotypical attitudes towards comics, as shown in a study that examined comics as a literary-didactic method as well as their use for reducing gender differences in reading literacy at the primary level of education (Kerneža & Košir, 2016). Wilson (2020), Sahara (2020), and Cheung and O'Sullivan (2017) state that there not only stereotypical attitudes towards comics, but also towards reading comics. Blank (2017), Jogie (2015), Hall (2011), and Armour and Ilda (2014) suggest that problems with the acceptance of comics may stem from a lack of appreciation of pop culture, with teachers fearing that such texts are frivolous, lack educational meaning (Lim, 2012) and are generally inappropriate (Clarke, 2013). In the existing literature, we find a great deal about stereotypes in comics (Chavez, 2021; Cruz, 2018; Dittmar, 2020) and breaking down stereotypes using comics (Loizou & Symienidou, 2019; Ostrow Seidler, 2015), but not about stereotypes about comics themselves. This also relates to teachers' stereotypical attitudes towards comics.

Method

Participants

A total of 139 teachers who were currently teaching the Slovenian language in a primary school from the first to the ninth grade (both class and subject teachers) participated in the research. Of them, 121 identified as female (87.1%) and 4 identified as male (2.9%), while 14 respondents chose not to answer the gender question (10.1%). Due to the small number of male teachers, the gender variable was excluded from further consideration.

At the lower level of primary education, the sample of teachers is evenly distributed (1^{st} grade – 18.7%, 2^{nd} grade – 17.3%, 3^{rd} grade – 15.8%, 4^{th} grade – 13.7%, 5^{th} grade – 12.2%). This is also the case regarding the upper level of primary education (6^{th} grade – 33.1%, 7^{th} grade – 33.1%, 8^{th} grade – 37.4%, 9^{th} grade – 38.8%). One respondent did not answer the question (0.7%).

Most of the teachers had 10–20 years (30.9%) of experience, while slightly fewer had taught for up to 10 years (23.0%), 20–30 years (22.3%) and over 30 years (21.6%). Three respondents did not answer the question (2.2%).

Most of the participating teachers had graduated from primary education programmes (54.7%), followed by Slavic studies/Slovenian studies or Slovenian language/literature (41.0%), while a few of the teachers had graduated from other fields (3.6%).

The highest level of education achieved, reported by more than half of the respondents (56.8%), is specialisation according to a higher professional programme, university programme (VII.) or master's degree (2^{nd} Bologna level), followed by a higher education programme (until 1994) or a post-secondary professional programme (VI/1.) (21.6%) and specialisation according to a higher education programme or higher professional programme (VI/2.) or a higher professional and university programme (1^{st} Bologna level) (17.3%). Four of the participants (2.9%) had completed a specialisation according to a university programme or master's degree (VIII/1.), while two of the participants (1.4%) are Doctors of Science (VIII/2. or 3^{rd} Bologna level).

The reading habits of the teachers were more favourable in the pre-adult period, and comics are less likely to be read by teachers in adulthood (Table 1).

Table 1

Number (f) and structural percentage (f%) of teachers according to their reading habits and their attitude towards reading comics

Period	Until adulthood		Today		Comics until adulthood		Comics today	
Frequency	f	f%	f	f%	f	f%	f	f%
Never	0	.0	3	2.2	15	10.8	54	38.8
Very rare	6	4.3	13	9.4	32	23.0	43	30.9
Rarely	10	7.2	24	17.3	43	30.9	34	24.5
Often	55	39.6	64	46.0	33	23.7	6	4.3
Very often	68	48.9	35	25.2	15	10.8	1	.7
Did not answer	0	.0	0	.0	1	.7	1	.7
Sum	139	100.0	139	100.0	139	100.0	139	100.0

Note. Until adulthood – frequency of reading until adulthood. Today – frequency of reading today. Comics until adulthood – frequency of reading comics until adulthood. Comics today – frequency of reading comics today.

Most of the teachers (45.7%) believe that they did not acquire competencies related to the introduction of comics in the classroom at the faculty. This is followed by those who believe that competencies related to the introduction of comics in the classroom were acquired during teaching itself (38.4%). Some 8.7% of the respondents acquired their knowledge at the faculty and 2.2% acquired it while working in study groups. One teacher (0.7%) gained her knowledge from her partner, one (0.7%) through online training, and one respondent did not give information about the origin of their knowledge (0.7%).

We were also interested in the attitude of Slovenian language teachers towards comics according to their reading habits in the period until adulthood and today. Overall, the reading habits of teachers have not changed, but there has been a reversal in those who enjoyed reading comics very much, or still enjoy reading them, as well as in those who did not read comics or do not like to read them today. The data are shown in Table 2.

Table 2

Number (f) and structural percentage (f%) of teachers' attitudes towards reading comics

Period	Until adulthood		Today	
Attitude towards reading comics	f	f%	f	f%
Really like	29	20.9	10	7.2
Like	51	36.7	57	41.0
Don't/Didn't like	14	10.1	28	20.1
Don't/Didn't like at all	15	10.8	10	7.2
Unformed	28	20.1	33	23.7
Didn't have access to comics	2	1.4	-	-
Did not answer	0	.0	1	.7
Sum	139	100.0	139	100.0

Note. Really like – I really like/liked to read comics. Like – I like/liked to read comics. Don't/Didn't like – I don't/didn't like to read comics. Don't/Didn't like at all – I don't/didn't like to read comics at all. Unformed – I don't/didn't have a formed attitude towards comics.

Most of the research that focuses on teachers' reading habits and attitudes towards reading is related to pre-service teachers. Research findings show that pre-service teachers are aware of the importance of reading and enjoy reading, but often do not find enough time to read (Uzum & Alincak, 2021), and that their reading habits are predicted by their attitudes towards reading (Aisyiyah & Hakim, 2020). Sahin and Bayrak (2021) state that teachers' reading habits are influenced by many factors, such as gender, teaching experience, the institution from which they graduated, level of education and level of job satisfaction. However, we did not find any studies comparing teachers' reading habits until adulthood and today, nor did we find any studies comparing teachers' reading habits to teachers attitudes towards reading comics.

The teachers in the present study also expressed agreement with stereotypical claims related to comics. Although they do not show explicit stereotypical attitudes towards comics, we can nevertheless see that there are differences even between the teachers who disagree with stereotypical claims (Table 3).

Table 3

Number (f) and structural percentage (f%) of teachers' agreement with stated stereotypical claims

Agreement	1		2		3		4		5		6		Sum	
Claim	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
S1	72	51.8	48	34.5	18	12.9	1	.7	0	.0	0	.0	139	100.0
S2	72	51.8	48	34.5	18	12.9	1	.7	0	.0	0	.0	139	100.0
S3	1	.7	1	.7	15	10.8	75	54.0	47	33.8	0	.0	139	100.0
S4	0	.0	4	2.9	35	25.2	66	47.5	34	24.5	0	.0	139	100.0
S5	71	51.1	56	40.3	10	7.2	1	.7	0	.0	1	.7	139	100.0
S6	94	67.6	41	29.5	3	2.2	1	.7	0	.0	0	.0	139	100.0
S7	40	28.8	46	33.1	33	23.7	18	12.9	2	1.4	0	.0	139	100.0
S8	60	43.2	57	41.0	21	15.1	1	.7	0	.0	0	.0	139	100.0
S9	60	43.2	51	36.7	25	18.0	3	2.2	0	.0	0	.0	139	100.0
S10	92	66.2	42	30.2	4	2.9	1	.7	0	.0	0	.0	139	100.0
S11	78	56.1	55	39.6	5	3.6	1	.7	0	.0	0	.0	139	100.0

Note. S1 – Comics are less worthy or worthless literature. S2 – Comics represent low culture. S3 – Comic art is diverse and rich. S4 – Comics are first-class graphic texts. S5 – Comics are for kids only. S6 – Comics are just for nerds. S7 – All comics include superheroes. S8 – Comics promote racial stereotypes. S9 – Comics promote gender stereotypes. S10 – Young people should not read comics. S11 – Comics do not belong in the school environment. 1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. 6 – No answer.

The Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text in the literacy curriculum are categorised in Table 4. According to the responses, the teachers' attitudes were categorised as positive or negative. Most of the teachers did not justify their opinions, but those who did justified their views with the objectives of the curriculum. One fifth of the teachers did not answer the question. The responses of the teachers who wrote a response reflected a lower level of knowledge in this area.

Table 4
Number (f) and structural percentage (f%) of expressed views of teachers about their attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum

Teachers' views	f	f%
Positive attitude related to the goals of the literary curriculum.	30	21.6
Positive attitude related to the goals of the language part of the curriculum.	5	3.6
Positive attitude related to the beliefs of the teacher.	2	1.4
Positive attitude under certain conditions.	7	5.0
Positive attitude.	56	40.3
Neutral position.	6	4.3
No answer.	33	23.8
Sum	139	100.0

The same applies to the teachers' attitudes towards the use of comics as a didactic method in literature classes (Table 5). Most of the teachers expressed positive opinions about the use of comics. In most cases, the teachers did not state reasons for their position, and if they did they expressed their reasons vaguely. About a third of the teachers did not answer the question. When we examined the responses more closely, we again concluded that the teachers were unaware of the field of comics.

Table 5
Number (f) and structural percentage (f%) of expressed views of teachers about their attitudes towards the use of comics as a literary-didactic method in literature classes

Teachers' views	f	f%
Positive attitude.	64	46.0
Positive attitude related to the goals of the literary curriculum.	2	1.4
Positive attitude related to the goals of the language part of the curriculum.	2	1.4
Positive attitude emanating from students.	5	3.6
Positive attitude resulting from the multimodal/cultural characteristics of comics.	1	.7
Positive attitude under certain conditions.	2	1.4
Neutral position.	5	3.6
Negative attitude (time consuming).	4	2.9
I don't know the method, I don't use it.	5	3.6
No answer.	49	35.3
Sum	139	100.0

The frequency of responses showing the teachers' attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum and towards the use of comics as a literary-didactic method in literature classes is consistent with previous research (Kerneža, 2020), which indicates that the teachers have positive attitudes towards the use of comics in the classroom, but do not know how to justify their attitudes. This may indicate insufficient competencies for teaching with comics or using a comic book.

Instruments

In order to test the research questions and hypotheses, a descriptive and causal-non-experimental method of quantitative empirical educational research was used. We approached answering the research questions comprehensively by using a questionnaire, which gave us a large and representative sample of teachers. In accordance with the objectives of the quantitative approach, we chose the direct technique, a four-part questionnaire.

In the first part of the survey, the teachers provided general information about themselves, which we used as independent variables: gender, educational period taught, professional experience, field of study, highest level of education completed, source of skills related to the introduction of comics in the classroom, reading habits, attitudes towards reading comics and agreement with stereotypical claims about comics

In the second part of the questionnaire, the teachers assessed the extent to which they agree (1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. 6 – No answer.) with the stated stereotypical statements about comics, which were arranged in a random order: *comics are less worthy or worthless literature, comics represent low culture, comic art is diverse and rich, comics are first-class graphic text, comics are for kids only, comics are just for nerds, all comics include superheroes, comics promote racial stereotypes, comics promote gender stereotypes, young people should not read comics,* and *comics do not belong in the school environment.* Attitudes are most commonly measured with Likert scale questionnaires (Taherdoost, 2019).

In the third part, the teachers answered two open-ended questions. They were asked about their views on the introduction of comics as an art-literary type of text in the literary curriculum and about their attitudes towards the use of comics as a literary-didactic method in literature classes.

The questionnaire was checked by relevant experts and tested on a sample of ten Slovenian language teachers. The validity, reliability and objectivity of the questionnaire were ensured. The reliability of the rating scales was checked using the Cronbach's alpha (α) coefficient. It was found that the scales are reliable (α = .603 for the teachers' reading habits rating scale; α = .603 for the teachers' stereotypical attitudes rating scale).

Research design

A web link to the questionnaire was sent to all Slovenian public and private primary schools, together with a request for participation, while a link to the survey was also posted on social networks.

The data from the questionnaires were statistically processed according to the objectives and predictions of the survey using the statistical software package SPSS for Windows. Descriptive statistics (frequencies and structural percentage) were used, as well as the chi-squared test.

Results

Introduction of comics as an art-literary type of text in the literary curriculum

We were interested in factors that influence Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum, and which stereotypical attitudes of Slovenian language teachers influence their decision. The results presented in Table 6 show no statistically significant differences in this context.

Table 6
The results of the chi-squared test of differences in terms of Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text according to the factors studied

Factor	χ^2	P
Educational period	25.815	.104
Professional experience	13.844	.739
Field of study	8.221	.768
Highest level of education completed	23.287	.503
Source of skills related to the introduction of comics in the classroom	33.925	.568
Reading habits until adulthood	24.421	.142
Reading habits today	22.921	.524
Frequency of reading comics until adulthood	21.412	.614
Frequency of reading comics in adulthood	31.560	.138
Attitude towards reading comics until adulthood	20.045	.915
Attitude towards reading comics in adulthood	17.804	.812

When investigating the influence of the stereotypical attitudes of Slovenian language teachers in relation to the introduction of comics as an art-literary type of text, only the correlation with the stereotype that *comics represent low culture* was statistically significant (Table 7).

Table 7

The results of the chi-squared test of differences in terms of Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum

Stereotypical attitudes	χ^2	P
Comics are less worthy or worthless literature.	22.767	.200
Comics represent low culture.	30.769	.031
Comic art is diverse and rich.	15.117	.917
Comics are first-class graphic texts.	9.746	.940
Comics are for kids only.	11.368	.878
Comics are just for nerds.	12.494	.821
All comics include superheroes.	19.822	.707
Comics promote racial stereotypes.	16.485	.559
Comics promote gender stereotypes.	16.042	.590
Young people should not read comics.	16.300	.572
Comics do not belong in the school environment.	12.946	.795

A more detailed analysis, presented in Table 8, shows that the teachers who disagree with the claim that comics represent low culture are mostly positive about the introduction of comics as part of the literature curriculum, and that slightly less than one third of the teachers express positive opinions in relation to the goals of the literature curriculum. Most of the teachers who disagree with the statement give a positive opinion, while a positive opinion is associated with a positive attitude related to the goals of the literature curriculum.

Table 8

Number (f) and structural percentage (f%) of teachers according to their attitude towards the introduction of comics as an art-literary type of text in the literary curriculum by agreement with the statement that comics represent low culture

Agreement	1		2		3		4		5		Sum	
Attitude	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
S1	19	13.8	8	6.0	3	2.2	0	.0	0	.0	30	21.7
S2	2	1.5	2	1.5	1	.7	0	.0	0	.0	5	3.6
S3	2	1.5	0	.0	0	.0	0	.0	0	.0	2	1.5
S4	4	2.9	2	1.5	1	.7	0	.0	0	.0	7	5.1
S5	30	21.7	19	13.8	7	5.1	0	.0	0	.0	56	40.6
S6	3	2.2	1	.7	1	.7	0	.0	0	.0	6	4.3
S7	11	8.0	16	11.6	5	3.6	1	.7	0	.0	32	23.2
Sum	71	51.4	48	34.8	18	13.0	1	.7	0	.0	138	100.0

Note. 1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. S1 – Positive attitude related to the goals of the literary curriculum. S2 – Positive attitude related to the goals of the language part of the curriculum. S3 – Positive attitude related to the beliefs of the teacher. S4 – Positive attitude under certain conditions. S5 – Positive attitude. S6 – Neutral position. S7 – No answer.

The results obtained should be considered from the perspective of the research of Alexio et al. (2020), who noted three different teacher views on comics in education: comics are considered a medium of children's entertainment and are not related to educational practice; if comics are used in education, they should be used primarily with students who need additional support; comics represent a 'missed opportunity in education' and have not reached their full potential due to the lack of comic resources for use in the classroom. The idea that comics represent low culture, an assertion that had statistically significant results, shows that culture covers a wide range (the term culture includes all products of an individual, group or society of intelligent beings) and can also include negative attitudes towards comics, as presented in the aforementioned study (Alexio et al., 2020), showing the relatedness between culture and attitudes, and confirming that teachers evaluate comics through the culture of society.

The use of comics as a literary-didactic method in literature classes

We were also interested in factors that influence Slovenian language teachers' attitudes towards the use of comics as a literary-didactic method in literature classes and which stereotypical attitudes of Slovenian teachers influence their literature teaching.

As in the analysis of the influence of the research factors on the attitude of Slovenian language teachers towards the introduction of comics as an art-literary type of text as part of the literature curriculum, there is no statistical effect of the studied factors on the attitudes of teachers to the use of comics as a literary didactic method in literature classes (Table 9).

Table 9

The results of the chi-squared test difference in terms of Slovenian language teachers' attitudes towards the introduction of comics as a literary-didactic method in literature classes according to the factors studied

Factor	χ^2	P
Educational period	28.798	.371
Professional experience	38.237	.074
Field of study	14.439	.700
Highest level of education completed	27.139	.856
Source of skills related to the introduction of comics in the classroom	59.486	.283
Reading habits until adulthood	20.062	.828
Reading habits today	20.794	.980
Frequency of reading comics until adulthood	43.995	.169
Frequency of reading comics in adulthood	28.411	.812
Attitude towards reading comics until adulthood	29.084	.968
Attitude towards reading comics in adulthood	28.474	.810

In the stereotypical attitudes of Slovenian language teachers towards the use of comics as a literary-didactic method in literature classes, there are statistically significant differences in agreement with the assertions that comics are diverse and rich, that young people should not read comics, and that comics do not belong in school (Table 10).

Table 10

The results of the chi-squared test of Slovenian language teachers' stereotypical attitudes towards the use of comics as a literary-didactic method in literature classes

Stereotypical attitudes	χ^2	P
Comics are less worthy or worthless literature.	27.696	.427
Comics represent low culture.	36.065	.114
Comic art is diverse and rich.	107.402	.000
Comics are first-class graphic texts.	38.181	.075
Comics are for kids only.	17.287	.924
Comics are just for nerds.	32.514	.214
All comics include superheroes.	41.125	.256
Comics promote racial stereotypes.	35.665	.123
Comics promote gender stereotypes.	35.768	.120
Young people should not read comics.	58.622	.000
Comics do not belong in the school environment.	50.174	.004

The results presented in Table 11 show that most teachers who consider that *comic art is diverse and rich* have a positive attitude towards comics. Other responses are scattered among the views expressed.

Table 11

Number (f) and structural percentage (f%) of teachers according to their attitude towards the introduction of comics as a literary-didactic method in literature classes by agreement to the statement that comic art is diverse and rich

Agreement	1		2		3		4		5		Sum	
Attitude	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
S1	0	.0	0	.0	7	5.0	33	23.7	24	17.3	64	46.0
S2	0	.0	0	.0	0	.0	0	.0	2	1.4	2	1.4
S3	0	.0	0	.0	0	.0	0	.0	2	1.4	2	1.4
S4	0	.0	0	.0	1	.7	4	2.9	0	.0	5	4.6
S5	0	.0	0	.0	0	.0	1	.7	0	.0	1	.7
S6	1	.7	0	.0	0	.0	1	.7	0	.0	2	1.4
S7	0	.0	0	.0	0	.0	3	2.2	2	1.4	5	4.6
S8	0	.0	0	.0	3	.2	1	.7	0	.0	4	2.9
S9	0	.0	0	.0	0	.0	1	.7	4	2.9	5	4.6
S10	0	.0	1	.7	4	.9	31	22.3	13	10.1	49	32.4
Sum	1	.7	0	.0	15	10.8	75	54.0	47	34.5	139	100.0

Note. 1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. S1 – Positive attitude. S2 – Positive attitude related to the goals of the literary curriculum. S3 – Positive attitude related to the goals of the language part of the curriculum. S4 – Positive attitude emanating from students. S5 – Positive attitude resulting from the multimodal/cultural characteristics of comics. S6 – Positive attitude under certain conditions. S7 – Neutral position. S8 – Negative attitude (time consuming). S9 – I don't know the method; I don't use it. S10 – No answer.

Most of the teachers interviewed disagree with the statement that *young people should not read comics*. Moreover, most of those who disagree with this statement also expressed a positive attitude towards the use of comics as a literary-didactic method in the classroom, and half as many teachers did not answer the question (Table 12).

Table 12

Number (f) and structural percentage (f%) of teachers according to their attitude towards the introduction of comics as a literary-didactic method in literature classes by agreement to the statement that young people should not read comics

Agreement	1		2		3		4		5		Sum	
Attitude	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
S1	49	32.4	14	10.1	1	.7	0	.0	0	.0	64	46.0
S2	2	1.4	0	.0	0	.0	0	.0	0	.0	2	1.4
S3	2	1.4	0	.0	0	.0	0	.0	0	.0	2	1.4
S4	3	2.2	2	1.4	0	.0	0	.0	0	.0	5	4.6
S5	0	.0	1	.7	0	.0	0	.0	0	.0	1	0.7
S6	1	.7	1	.7	0	.0	0	.0	0	.0	2	1.4
S7	4	2.9	0	.0	1	.7	0	.0	0	.0	5	4.6
S8	1	0.7	1	.7	2	1.4	0	.0	0	.0	4	2.9
S9	5	4.6	0	.0	0	.0	0	.0	0	.0	5	4.6
S10	25	18.0	23	16.5	0	.0	1	.7	0	.0	49	32.4
Sum	92	64.3	42	30.1	4	2.9	1	.7	0	.0	139	100.0

Note. 1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. S1 – Positive attitude. S2 – Positive attitude related to the goals of the literary curriculum. S3 – Positive attitude related to the goals of the language part of the curriculum. S4 – Positive attitude emanating from students. S5 – Positive attitude resulting from the multimodal/cultural characteristics of comics. S6 – Positive attitude under certain conditions. S7 – Neutral position. S8 – Negative attitude (time consuming). S9 – I don't know the method; I don't use it. S10 – No answer.

Most of the teachers who disagreed with the statement that *comics do not belong in the school environment* also expressed a positive attitude towards the use of comics as a literary-didactic method in the classroom (Table 13).

Table 13

Number (f) and structural percentage (f%) of teachers according to their attitude towards the introduction of comics as a literary-didactic method in literature classes by agreement to the statement that comics do not belong in the school environment

Agreement	1		2		3		4		5		Sum	
Attitude	f	f%	f	f%	f	f%	f	f%	f	f%	f	f%
S1	45	32.4	18	13.0	1	.7	0	.0	0	.0	64	46.0
S2	2	1.4	0	.0	0	.0	0	.0	0	.0	2	1.4
S3	2	1.4	0	.0	0	.0	0	.0	0	.0	2	1.4
S4	3	2.2	2	1.4	0	.0	0	.0	0	.0	5	4.6
S5	0	.0	1	.7	0	.0	0	.0	0	.0	1	.7
S6	1	.7	1	.7	0	.0	0	.0	0	.0	2	1.4
S7	1	.7	3	2.2	1	.7	0	.0	0	.0	5	4.6
S8	1	.7	1	.7	2	.4	0	.0	0	.0	4	2.9
S9	4	2.9	1	.7	0	.0	0	.0	0	.0	5	4.6
S10	19	13.7	28	20.1	1	.7	1	.7	0	.0	49	32.4
Sum	78	56.1	55	39.5	5	4.6	1	.7	0	.0	139	100.0

Note. 1 – I do not agree at all. 2 – I do not agree. 3 – I neither agree nor disagree. 4 – I agree. 5 – I very much agree. S1 – Positive attitude. S2 – Positive attitude related to the goals of the literary curriculum. S3 – Positive attitude related to the goals of the language part of the curriculum. S4 – Positive attitude emanating from students. S5 – Positive attitude resulting from the multimodal/cultural characteristics of comics. S6 – Positive attitude under certain conditions. S7 – Neutral position. S8 – Negative attitude (time consuming). S9 – I don't know the method; I don't use it. S10 – No answer.

Comics are widely used as a didactic method to achieve the curriculum goals in the classroom and are generally accepted as a didactic method that can be used in the classroom in a variety of subjects and domains (e.g., Chu & Toh, 2020; Matuk et al., 2019; Sagri et al., 2019). This is consistent with the findings of our study showing that teachers who expressed positive attitudes towards the use of comics as a literary-didactic method in the classroom disagreed with the statement that comics do not belong in the school environment.

Discussion

The study shows that the factors of gender, educational period taught, professional experience, field of study, highest level of education completed, source of skills related to the introduction of comics in the classroom, teachers' reading habits and their attitudes towards reading comics, and agreement with stereotypical claims about comics have no influence on Slovenian language teachers' attitudes towards the use of comics in literature classes, either in the form of an art-literary type of text or in the form of a literary-didactic method.

Statistically significant differences appeared only when teachers' stereotypical attitudes towards comics were introduced as a variable. The analysis shows a statistically significant difference between teachers who agreed with the introduction of comics as an art-literary type of text in the case of the claim that *comics represent low culture*. The attitudes towards claims about comics that influence attitudes towards the use of comics as a literary-didactic method are: *comic art is diverse and rich, young people should not read comics* and *comics do not belong in the school environment.* Many of the questions either remained unanswered or the teachers did not provide an answer corresponding to the question asked. It was found that teachers do not understand the difference between the two researched uses of comics, nor can they confidently place the researched uses of comics in the curriculum. Since comics are part of the Slovenian language curriculum (Poznanovič Jezeršek et al., 2018), there is an urgent need to train teachers in the field of using comics in Slovenian language teaching, where we can apply the method mentioned by Schoenfeld (2020), that is, by influencing teachers' perceptions, inclinations and orientations in the field of using comics in Slovenian language teaching. How can this be achieved? Since both picture books and comics are multimodal texts (Batič & Haramija, 2014), picture books and teachers' knowledge about picture books would be an important tool to influence teachers' attitudes towards comics.

We can now answer the research questions. Slovenian language teachers' attitudes towards the introduction of comics as an art-literary type of text in the literary curriculum are predominantly positive. They are most often associated with the aims of the literary curriculum and are influenced by teachers' stereotypical attitudes towards the claim that *comics represent low culture*. Fewer teachers supported the use of comics as a literary-didactic method in the classroom; the answers were more scattered and more teachers expressed a negative opinion, stating that they do not know the method and therefore do not use it. This is also reflected in the teachers' responses, as most of them simply stated that they have a positive attitude towards the use of comics as a literary-didactic method, without giving any further reasons for their decision. The results show that the attitude of Slovenian language teachers towards the use of comics as a literary-didactic method is influenced by their attitude towards claims that *comic art is diverse and rich*, *young people should not read comics* and *comics do not belong in the school environment*. The results also confirm the assumption that stereotypical attitudes towards comics still exist among teachers (Kerneža, 2016).

The results presented partially confirm the hypothesis. The most important finding of the study is that teachers' concerns about the use of comics in the classroom are mainly due to insufficient knowledge about the researched ways of including comics in the literature classroom. Block (2013) also notes that the majority of teachers use graphic novels at most once a year, even though they believe this text format is useful and motivates students. Most teachers have not received training on the use of graphic novels and indicate that they would probably use them more often if they had more knowledge about them. The specified data contrasts with the research of Batič (2021) on the use of picture books, which shows that teachers have no problems selecting suitable picture books for use in the classroom. This highlights the need for quality educational programmes. In order to reach the widest possible range of teachers, it would be appropriate to familiarise pre-service teachers with quality (didactic) comic contents. Since a comic consists of a picture and a text, this training should cover both concepts: the artistic one that students should learn in art classes, and the literary one that students should learn in literature classes. For in-service teachers (and pre-service teachers) we see great value in sharing best practices, whereby teachers who have a good, positive and unencumbered attitude towards comics would most likely share their experience and knowledge of using comics in Slovenian language classes. Research shows the influence of enthusiasm on student performance (Mahler et al., 2018), which could be the most important element to influence teachers' perception, inclination and orientation (Schoenfeld, 2020) towards comics. The findings are consistent with the previously discussed findings of Abdulrauf et al. (2016) that teachers' subject knowledge and skills are closely related to the their views and the transmission of their views to their students (Zhang et al., 2018). Teachers' confidence is stronger when we talk about comics as an art-literary type of text. Comics as a literary-didactic method are not sufficiently known among teachers to be able to confidently report their use in literature classes and teachers are hesitant to use them due to their lack of knowledge.

Conclusion

The present study attempts to address gaps in the research on teachers' attitudes towards the use of comics in Slovenian language classes. It extends the limited research on understanding teachers' attitudes towards the introduction of comics and literature instruction in primary school. It is also one of the first studies to address specific stereotypical attitudes towards comics, and it has even greater relevance to the field of the use of comics in literature instruction, as – to the best of authors' knowledge and based on a search of peer-review databases – no previous research has examined teachers' attitudes towards the use of comics in native language instruction. This is especially important since it was found that teachers do not have enough knowledge about the two forms of comic use in the classroom: they do not distinguish between comics as an art-literary type of text and comics as a didactic method. The teachers' responses are therefore questionable at some points of the research, as they may not have interpreted the above uses of comics correctly. The results reflect the great need for teacher training to enable teachers to use and introduce comics in all forms in literature classes. Two target groups are proposed in identifying the need for additional teacher training. The first is future teachers of Slovenian language, who, through well-designed didactic units, can learn that comics can also be texts of literary and artistic quality. Another way to promote teachers' positive opinions about the use of comics in Slovenian language teaching is to share the best practices of teachers who already use comics in their teaching. These teachers could, through their good example and enthusiasm, adequately motivate other teachers to use comics as an art-literary type of text as part of the literature curriculum and as a literary-didactic method in literature classes.

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Perceptions of Didactic Strategies among Pupils and Teachers in Primary School

Monika Mithans*[1], Joca Zurc[2] and Milena Ivanuš Grmek[3]

~ The quality of educational work is inextricably linked to many factors at the system, school, teacher, and student levels. This research was carried out within the project 'Education of Teachers as a Factor of Providing High-quality Life-long Learning in the Learning Society/The Society of Fast Socio-economic Changes and Unsure Future', funded by the Slovenian Research Agency. This paper provides a basic overview of the characteristics of open instruction, an umbrella term that combines active and learner-centred didactic strategies. The empirical section focuses on the use of didactic strategies. The survey was carried out with 1,536 primary school[4] pupils in Grades 7 and 9 and 263 of their teachers. Both pupils and teachers cited problem-based learning and research-based learning as the most commonly used didactic strategies, while project-based learning was the least frequently used. Despite the agreement on the most and least frequently used didactic strategies, there are statistically significant differences between pupils' and teachers' perceptions of all selected didactic strategies. Teachers reported that they used these strategies more often than was perceived by their pupils. We also found a statistically significant impact of better learning performance on the perception of certain didactic strategies. The results of the study raise new research questions, especially in the design of more detailed analyses of the use of didactic strategies in pedagogical practice.

Keywords: academic performance, didactic strategies, primary school, pupil activity

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Zaznavanje strategij pouka med učenci in učitelji v osnovni šoli

Monika Mithans, Joca Zurc in Milena Ivanuš Grmek

Kakovost vzgojno-izobraževalnega dela je neločljivo povezana s številnimi dejavniki na ravni sistema, šole, učiteljev in učencev. Raziskava, katere del predstavljamo v tem prispevku, je potekala v okviru projekta Izobraževanje učiteljev kot dejavnik zagotavljanja kakovostnega vseživljenjskega učenja v učeči se družbi/v družbi hitrih družbeno-gospodarskih sprememb in negotove prihodnosti, ki ga je financirala Javna agencija za raziskovalno dejavnost Republike Slovenije (ARRS). Prispevek ponuja grob pregled značilnosti odprtega pouka, ki kot nadpomenka združuje aktivne in v učence usmerjene strategije pouka. V empiričnem delu smo pozornost usmerili v preučevanje pogleda učencev in učiteljev na uporabo strategij pouka v pedagoški praksi. V raziskavi je sodelovalo 1.536 učencev 7. in 9. razreda osnovne šole in 263 njihovih učiteljev. Ugotovili smo, da učenci in učitelji kot najpogosteje uporabljeni strategiji pouka navajajo problemski in raziskovalni pouk, najredkeje pa se po mnenju obojih pojavlja projektni pouk. Kljub enotnosti o najpogosteje in najredkeje uporabljenih strategijah pouka med učenci in učitelji prihaja do statistično značilnih razlik v zaznavanju vseh strategij pouka. Učitelji namreč navajajo, da omenjene strategije uporabljajo pogosteje, kot to zaznavajo njihovi učenci. Ugotovili smo tudi statistično značilen vpliv boljšega učnega uspeha na zaznavanje nekaterih strategij pouka. Izsledki naše raziskave odpirajo nova raziskovalna vprašanja, predvsem pri načrtovanju podrobnejših analiz uporabe strategij pouka v pedagoški praksi.

Ključne besede: učni uspeh, strategije pouka, osnovna šola, aktivnost učencev

Introduction

Education and knowledge are indispensable assets and prerequisites for successful social and economic development. This is why there is increasing demand for more effective learning and teaching processes (Pelc, 2008).

Experts agree that pupils should be active participants in the educational process (Alvia & Gillies, 2020; Mithans, 2017; Mithans et al., 2017) in subjects with the possibility for active participation (Blažič et al., 2003; Mithans & Ivanuš Grmek, 2012).

Consequently, the role of the teacher, who was once the sole source and transmitter of knowledge (Holt-Reynolds, 2000), must also change (Kalin et al., 2017; Tahirsylaj et al., 2021). In a knowledge society, it is the teacher's effectiveness that is key to the effectiveness of the entire education system (Yar Yildirim, 2021). Therefore, teachers need to strive continuously to improve their educational work (Šorgo & Heric, 2020), to educate themselves throughout their careers, and to upgrade their knowledge (Torres-Cladera et al., 2021). The teacher is no longer merely a transmitter of knowledge. Increasingly, the role of the teacher is that of facilitator, animator and organiser of a stimulating learning environment, mentor, and promoter of independent learning (Cencič et al., 2008). Research shows that learning results are mainly determined by the quality of teaching (Hattie, 2008; Rowe, 2003; Timperley & Alton-Lee, 2008). It is, therefore, important that the teacher motivates and empowers pupils to learn independently and chooses didactic strategies that put them in the role of active agents (Kalin et al., 2017). The ability to use a variety of didactic strategies is thus one of the most important characteristics of an effective teacher (AgwuUdu, 2019).

The main purpose of this study is to identify the factors that contribute to the quality of educational work in primary schools. In this article, we will answer the question of which didactic strategies are most used in the upper grades of Slovenian primary schools and how the perception of them is influenced by academic performance.

Didactic Strategies

A strategy is 'a deliberate, planned process for achieving a set goal that guides one's overall behaviour' (Valenčič Zuljan & Kalin, 2020, p. 117). Similarly, didactic strategies concretise teachers' and pupils' learning activities towards achieving educational goals (Valenčič Zuljan & Kalin, 2020) and represent teachers' planned selection of teaching methods and forms (Strmčnik, 2001).

According to Valenčič Zuljan and Kalin (2020), the didactic strategy includes both traditional teaching (direct instruction) and different types of open instruction (Blažič et al., 2003; Peschel, 2010).

In our study, we rely on the definition developed by Blažič et al. (2003), which sees open instruction as a superset of, characterised by teachers not sticking rigidly to learning objectives, content, and methods but adapting them to the interests and abilities of their pupils. Modern didactic strategies focus on the life of the local community and on pupils' anticipation and participation in learning.

In the view of Blažič et al. (2003), these principles and other characteristics of open instruction are most clearly reflected in didactic strategies such as experiential learning, research-based learning, project-based learning, problem-based learning, action-oriented learning, cross-curricular learning, among others. These didactic strategies require teachers to teach actively and pupils to learn actively (Blažič et al., 2003; Ivanuš Grmek et al., 2009) and to cooperate with each other. They put the learner at the centre, giving them greater autonomy to learn and offering self-paced and personalised learning. As a consequence, these didactic strategies positively impact the sustainability and usability of knowledge and on, the development of creativity and critical thinking and contribute to the development of lifelong learning competences (Alvia & Gillies, 2020; Cencič et al., 2008; Filippatou & Kaldi, 2010; McPherson-Geyser et al., 2020). Their main goal is to enable the learner to play an active role in shaping his or her own learning (Cencič et al., 2008).

These didactic strategies share a tendency to link learning to pupils' prior knowledge and experiences, as well as to the learners' present. Pupils are given the opportunity to participate according to their abilities, which also helps to reinforce the principles of inclusive education (Alvia & Gillies, 2020; Filippatou & Kaldi, 2010).

Through didactic strategies, pupils learn new content in an active way by justifying their ideas, giving reasons for the correctness of the solutions given, and contributing to higher-quality learning outcomes through independent inquiry and reflection (Ivanuš Grmek et al., 2009).

By incorporating pupils' preferences and needs, these didactic strategies make a decisive contribution to increasing learning motivation and, consequently, learning performance (Ing et al., 2015). Other researchers have also shown a positive correlation between pupil activity and pupil performance (Fredricks et al., 2004). Keeping pupils highly engaged and active during lessons is one of the most important and challenging tasks for a teacher (Kozina & Vršnik Perše, 2015); this skill is still not sufficiently implemented in pedagogical practice (Crook & Cox, 2022; Deslauriers et al., 2019; Mithans, 2017; Mithans et al., 2017; Mithans & Ivanuš Grmek, 2019).

The positive effects of open instruction on learning performance, self-regulation skills, critical thinking development, participants' attitudes, and similar factors are evidenced by the results of numerous studies (Alvia & Gillies, 2020; Cotič et al., 2020; Darhim et al., 2020; Fernandes, 2021; Ferrero et al., 2021; Harris & Bilton, 2019; Kaldi et al., 2009; Lazić et al., 2021; Sutrisna & Artini, 2020). However, for reasons of time efficiency and control over classroom work, traditional frontal teaching remains the dominant pedagogical practice (Plešec Gasparič, 2019); it is effective for achieving basic knowledge but less effective for learning more complex and creative content (Valenčič Zuljan & Kalin, 2020).

In the face of the constant changes and challenges of the present for the wider community, learner-centred teaching, made possible by open instruction, must find its way into pedagogical practice: to achieve all the goals of the educational process, it is necessary to combine different didactic strategies at all levels of education and to choose them according to the individual characteristics of the pupils.

The didactic competence of teachers and their willingness to improve continuously in this area is essential for the successful implementation and combination of didactic strategies that will truly enable the acquisition of in-depth knowledge and foster criticality and creativity. According to Revelle (2019), teachers play a central role in introducing new or different didactic strategies.

Research Problem and Aims

The results of our previous research indicate that student participation remains a challenge (Mithans et al., 2017) and that student participation also largely depends on open instruction (Mithans & Ivanuš Grmek, 2019).

Based on the benefits of open instruction, we were interested in which didactic strategies are most commonly used in the upper grades of Slovenian primary schools. We focused on pupils' perceptions of didactic strategies and on teachers' self-assessment of their use of particular didactic strategies. We were also interested in the role of the pupil's school performance in the perception of these strategies. The two initial hypotheses were as follows:

H1: There are statistically significant differences between primary school pupils' and teachers' perceived frequency of use of didactic strategies.

H2: School performance is a statistically significant indicator of differences in the perceived frequency of use of didactic strategies in pupils.

Method

The research is based on a survey methodology, using a questionnaire for pupils in Grades 7 and 9 in Slovenian primary schools and their teachers.

Sample of respondents

The survey was carried out with 1,536 primary school pupils in Grades 7 and 9 and 263 of their teachers. A random stratified representative sample was selected, including all 12 Slovenian statistical regions, with a random selection of 5 per cent of all primary schools in the Republic of Slovenia as the criterion. The demographic characteristics of the pupils and their teachers are shown in Tables 1 and 2.

Table 1

Demographic characteristics of the sample of pupils

Characteristic		n	f %	M (SD)	Min.–Max.
Gender	Girl	792	51.7	/	/
	Boy	739	48.3		
Age (years)	12	379	24.8	13.46 (1.10)	12–15
	13	416	27.2		
	14	381	25.0		
	15	351	23.0		
Grade	7	820	53.4	/	/
	9	716	46.6		

Note. M = mean; SD = standard deviation; / = could not be calculated given the nature of the test variables.

Nearly equal proportions of female pupils (51.7%) and male pupils (48.3%) participated in the survey. The average age of the respondents was 13.46 years. There was a slightly higher proportion of pupils aged 13 (27.2%) and 14 (25%) and a slightly lower, but evenly distributed, proportion of pupils aged 12 and 15. By grade, the respondents came from Grades 7 and 9 of primary school, with a slightly higher proportion of Grade 7 pupils (53.4%) (Table 1).

Table 2

Demographic characteristics of the sample of teachers

Characteristic		n*	f %	M (SD)	Min.–Max.
Gender	Women	214	81.7	/	/
	Men	48	18.3		
Age (years)	25–35	44	16.7	45.92 (9.92)	25-66
	36–45	92	35.1		
	46–55	67	25.6		
	56 and over	59	22.5		
Professional title	Without promotion	50	19.2	/	/
	Mentor	83	31.8		
	Advisor	101	38.7		
	Counsellor	27	10.3		
Formal education	Teacher education	246	94.3	/	/
	Non-teaching degree with PAI	15	5.7		
Subject area	Foreign languages	41	15.6	/	/
	Slovenian	30	11.4		
	Mathematics	25	9.5		
	Sport	30	11.4		
	Arts courses	21	8.0		
	Study orientations	116	44.1		

Note. M = mean; SD = standard deviation; / = could not be calculated given the nature of the test variables.
* There is a discrepancy in the demographic characteristics of the sample, with some teachers not answering all demographic questions.

Table 2 shows that 81.7 per cent of the teachers participating in the survey were female and 18.3 per cent were male. The average age of the respondents was 45.9 years, with a standard deviation of 10 years, which means that most of the teachers surveyed were aged between 36 and 56 years. This is confirmed by the frequency distribution of age groups, which places 60.7 per cent of the teachers surveyed in the 36–55 age group. The oldest teacher in the study was 66 years and the youngest 25 years. Most of the participants had already achieved the title of Advisor (38.7%) or Mentor (31.8%). The majority of the teachers (94.3%) had completed teacher-training degree programmes, while 5.7 per cent of the teachers surveyed had obtained their teaching qualifications through the Pedagogical-Adult Education (PAI) programme.

Measuring Instrument

A closed-ended questionnaire was used to collect the data. There were two versions of the questionnaire: one to be completed by the pupils and one by their teachers. Both questionnaires included demographic questions such as gender and age in the introductory part.

For pupils, the demographic section was complemented by questions on the school grade and final grades in Slovenian, mathematics and the first foreign language. Based on the final grades collected, a new variable, 'academic performance', was created for further analysis, representing the overall average score of the final grades in the three subjects. The demographic section of the teacher questionnaire also included questions on the professional title, type of formal education received, and subject(s) taught.

The demographic questions were followed by 14 variables defining didactic strategies. The set of these variables was identical on both versions of the questionnaire, with a slight difference in the format to address each group of respondents adequately. Pupils and teachers rated the frequency of use of the selected didactic strategies on a three-point scale (3 = frequently, 2 = rarely, 1= never). The measurement instrument was tested in a case study in the north-eastern part of the Republic of Slovenia.

Table 3 shows the results of the calculated Cronbach alpha coefficients, which were used to assess the reliability of the questionnaires by scale. For all three rating scales studied, we found adequate reliability of the data collected, as Cronbach's alpha coefficient showed values ranging from 0.78 to 0.84, thus confirming adequate reliability of the questionnaire for both pupils and teachers.

Table 3

Assessing the reliability of the questionnaire on pupils' perceptions of didactic strategies and school performance and the questionnaire on teachers' self-assessment of their use of didactic strategies

Rating scale		Number of variables (n)	Cronbach's alpha
Pupils	Didactic strategies	14	0.797
	Academic performance	3	0.835
Teachers	Didactic strategies	14	0.780

Data Collection Process and Ethical Considerations

Data collection took place from May to June 2019, using a face-to-face approach (paper-pencil) in the primary schools included in the survey. The data collection was carried out with the help of school coordinators, who helped us to carry out the survey. The coordinators worked with the teachers, collected the questionnaires, and helped with the organisational arrangements for the survey.

All data collection was carried out in accordance with the fundamental approaches of research ethics, such as anonymity, voluntary participation, and the possibility to withdraw from the research at any time without consequences for the participant. For all pupils surveyed, parents or legal guardians gave written consent to participate in the survey before data collection began.

Data Analysis Methods

All analyses were carried out using SPSS statistical software, version 26.0. Firstly, measures of descriptive statistics were calculated for all variables. Depending on the type of variable, we calculated frequencies and percentages (nominal and ordinal variables), as well as calculated measures of the front values and the dispersion of the data (means, standard deviations, minimum and maximum, skewness and kurtosis). Further analyses were performed to check whether the conditions for inferential statistics were met, such as Cronbach's alpha coefficients to determine the reliability of the data, the Kolmogorov-Smirnov test for normality of distribution, Pearson's correlation coefficient, and a scatter plot to determine the linear dependence between variables.

In the next step, the variables assessing the didactic strategies were grouped into categories using qualitative categorical analysis. The 14 statements assessed were grouped into the following five didactic strategies: experiential learning (n=4), problem-based learning (n=3), research-based learning (n=3), cross-curricular learning (n=2) and project-based learning (n=2).

To test the hypotheses, we used linear regression and t-tests for dependent samples. Differences at $p \leq 0.05$ were considered statistically significant. The interpretation of the results also took into account the effect sizes of the statistical tests (Cohen's d, beta).

Results

Pupils' and Teachers' Perceptions of Didactic Strategies

Table 4

Comparison between pupils' and teachers' perceptions of didactic strategies

Didactic strategy	Pupils	Teachers	t (p)	Cohen's d
	M (SD)*	M (SD)*		
Problem-based learning	2.28 (0.47)	2.67 (0.37)	**-15.090 (<0.001)**	0.458
Research-based learning	2.21 (0.37)	2.55 (0.29)	**-16.368 (<0.001)**	0.362
Experiential learning	1.97 (0.42)	2.48 (0.46)	**-16.821 (<0.001)**	0.430
Cross-curricular learning	1.92 (0.51)	2.41 (0.39)	**-17.457 (<0.001)**	0.494
Project-based learning	1.65 (0.50)	1.93 (0.60)	**-7.239 (<0.001)**	0.518

Note: * rating scale: 1 = never, 2 = rarely, 3 = frequently; M = mean; SD = standard deviation; Cohen's d = effect size of t-test

The results in Table 4 show that pupils in Grades 7 and 9 of primary school perceived problem-based learning (M=2.28, SD=0.47) and research-based learning (M=2.21, SD=0.37) as the most frequently used didactic strategies. Teachers also said these were the two most commonly used didactic strategies.

Despite the finding that problem-based and research-based learning are the didactic strategies most perceived by both pupils and teachers, they are still perceived by pupils to be rare, while teachers judge that they are often included in their teaching. According to pupils, teachers also rarely used experiential learning (M=1.97, SD=0.42) or cross-curricular learning (M=1.92, SD=0.51), while teachers were fairly unanimous in their opinion that they include experiential (M=2.48, SD=0.46) and cross-curricular learning (M=2.41, SD=0.39) more often in their teaching.

Project-based learning was perceived by children to be the least represented strategy (M=1.65, SD=0.50), occurring rarely or never. Teachers also perceived project-based learning as the least represented strategy (M=1.93, SD=0.60), occurring rarely or never.

Teachers ranked the presence of all five assessed didactic strategies statistically significantly higher than pupils ($p < 0.001$). Cohen's d effect size, with values ranging from 0.36 to 0.52, indicates a medium-strong effect size for statistically significant differences between pupils' and teachers' opinions. The most marked difference was found in the least represented didactic strategy, namely project-based learning (0.52).

The pupils surveyed were quite unanimous in their opinions (SD≤0.51) when evaluating all strategies. The greatest unanimity was found in their assessment of the incidence of research-based learning (84.7% perceived that it was rarely present). Pupils' opinions were slightly more divided when it came to rating the incidence of cross-curricular teaching, which may reflect different perceptions of this didactic strategy among pupils.

Similarly, the teachers surveyed showed the highest level of agreement (SD=0.29) in their assessment of the use of research-based learning (72.7% of them used it frequently). The teachers' opinions were most divided when it came to project-based learning (SD=0.60), which was used frequently by 27.1% of respondents and never by 14.1%.

Table 5

The incidence of the didactic strategies that pupils think their teachers use

Didactic strategy	Statement	M (SD)	Min.–Max.
Problem-based learning	Teachers prepare assignments and encourage us to find sources and solutions independently.	2.44 (0.63)	1–3
	Teachers present us with a problem (a question) and let us find our own solutions.	2.22 (0.67)	1–3
	Teachers encourage us to detect problems (open questions) as they teach.	2.19 (0.67)	1–3
Research-based learning	Teachers encourage us to formulate research questions and find answers to them.	2.55 (0.59)	1–3
	Teachers guide us to come to our own conclusions through research.	2.41 (0.61)	1–3
	Teachers encourage us to express our own ideas and thoughts about solutions to the research problem.	2.27 (0.65)	1–3
	We also do research outside the classroom (in the library, in the laboratory, in nature, etc.).	1.62 (0.57)	1–3
Experiential learning	Teachers include observation of paintings, art techniques, films, etc.	2.28 (0.64)	1–5
	Teachers also integrate our experience of the content into their lessons.	2.08 (0.67)	1–3
	We play different roles in the classroom.	1.54 (0.60)	1–3
Cross-curricular learning	Teachers integrate the content of different subjects in their lessons.	2.22 (0.66)	2–3
	The lessons are taught simultaneously by teachers of different subjects, each presenting their own aspect.	1.63 (0.74)	1–3
Project-based learning	Teachers involve us in projects.	1.76 (0.72)	1–3
	With the help of teachers, we work on project assignments.	1.53 (0.58)	1–3

Three features of inquiry- and problem-based learning that encourage independent learning, research and problem-solving were rated by pupils as frequently occurring: ‘Teachers encourage us to formulate research questions and find answers to them’ (M=2.55); ‘Teachers prepare assignments and encourage us to find sources and solutions independently’ (M=2.44); and ‘Teachers guide us to come to our own conclusions through research’ (M=2.41).

Table 6

Teachers’ self-assessment of didactic strategies

Didactic strategy	Statement	M (SD)	Min.–Max.
Problem-based learning	I encourage pupils to perceive problems by presenting the learning content.	2.79 (0.43)	1–3
	I present the problem and let the pupils find their own solutions.	2.70 (0.47)	1–3
	I prepare assignments and encourage pupils to find sources and solutions independently.	2.52 (0.55)	1–3
Research-based learning	I encourage pupils to express their own ideas and thoughts about possible solutions to the research problem.	2.89 (0.34)	1–3
	I guide pupils to come to their own conclusions through research.	2.76 (0.44)	1–3
	I prepare materials and encourage pupils to formulate their own research questions and find their own answers.	2.54 (0.52)	1–3
	We also do research outside the classroom (in the library, in the laboratory, in nature, etc.).	2.01 (0.63)	1–3
Experiential learning	I integrate the pupils’ experiences into my lessons.	2.82 (0.41)	1–3
	I include observation of paintings, art techniques, films, etc., in my teaching.	2.41 (0.70)	1–3
	I organise the lessons in such a way that the pupils play different roles.	2.22 (0.71)	1–3
Cross-curricular learning	In my teaching, I integrate the content of different subjects.	2.85 (0.35)	2–3
	Teachers from different subjects come together to present their points of view.	1.97 (0.62)	1–3
Project-based learning	We work with pupils on project assignments.	1.96 (0.71)	1–3
	I involve pupils in projects.	1.90 (0.72)	1–3

Among the individual statements in Table 6, teachers gave the highest rating to the statement, ‘I encourage pupils to express their own ideas and thoughts about possible solutions to the research problem‘ (M=2.89, SD=0.34). This statement falls under research-based learning. Teachers also rated very highly (M≥0.8) didactic strategies that integrate cross-curricular integration (team integration), pupil experiences (experiential learning), and encouraging pupils to identify problems (problem-based learning).

Academic Performance as a Determinant of Pupils' Perceptions of Didactic Strategies

In this section, we present the results in relation to the second hypothesis, which tested how average academic performance predicts pupils' perceptions of didactic strategies. Table 7 shows the average final grades of the surveyed pupils in the three core subjects of primary education, namely Slovenian language, mathematics and (first) foreign language, as well as the overall average grade for all three. Primary school pupils achieved the highest average score in a foreign language (3.82), followed by Slovenian (3.60) and mathematics (3.54). The overall mean score was 3.66 (SD=0.91).

Table 7

Academic performance of pupils surveyed

Subject area	Total	Grade 7	Grade 9
	M (SD)	M (SD)	M (SD)
Slovenian*	3.60 (1.00)	3.66 (1.00)	3.52 (1.00)
Mathematics	3.54 (1.10)	3.57 (1.10)	3.51 (1.09)
(First) foreign language	3.82 (1.07)	3.86 (1.08)	3.78 (1.05)
Average academic performance	3.66 (0.91)	3.70 (0.92)	3.60 (0.91)

Note. M = mean; SD = standard deviation; p = statistical significance of the test; * final grade in the previous school year: 1 = unsatisfactory, 2 = satisfactory, 3 = good, 4 = very good, 5 = excellent; the average academic performance is the combined average of the final grades in Slovenian, mathematics and (first) foreign language.

Linear regression was used to investigate the relationship between pupils' perceptions of didactic strategies and their academic performance. Linear regression is particularly suited to identifying influences and relationships between two variables and predicting the outcome of the dependent variable based on changes in the value of the independent variable. Before the calculation, we checked that the variables we wanted to include in the regression analysis (i.e., the final grades in Slovenian, mathematics and foreign language, and the grades of all the included didactic strategies) met the conditions. The distribution normality of the variables was checked using the skewness and kurtosis coefficients and the Kolmogorov-Smirnov test. Linear correlation between dependent variables was established using Pearson's correlation coefficient and a scatter plot. The variables included were shown to meet the conditions for inclusion in the linear regression.

Table 8

Linear regression of the effect of pupils' academic performance on their perceptions of the incidence of didactic strategies

Didactic strategy (dependent)	Academic performance (independent)	B	Beta	R^2	F (p)
Problem-based learning	Average academic performance	0.048	**0.093***	0.009	**12.914 (0.001)**
Research-based learning	Average academic performance	0.051	**0.125***	0.016	**23.645 (<0.001)**
Experiential learning	Average academic performance	0.023	0.049	0.002	3.568 (0.059)
Cross-curricular learning	Average academic performance	-0.051	**-0.091***	0.008	**12.221 (<0.001)**
Project-based learning	Average academic performance	0.014	0.025	0.001	0.923 (0.337)

Note. B = unstandardised coefficient; Beta = standardised coefficient; R^2 = proportion of explained variance of the model; F (p) = statistical significance of the model: one-factor analysis of variance (ANOVA); * statistical significance of partial correlation $p \leq 0.001$; Average academic performance = calculated average grade from the final grade in Slovenian, mathematics and the first foreign language.

The linear regression showed that pupils' performance in primary school, calculated based on the average of their final grades in the three core subjects (Slovenian, mathematics, and foreign language), is a statistically significant predictor of their perception of three didactic strategies, namely experiential learning ($p < 0.001$), cross-curricular learning ($p < 0.001$) and problem-based learning ($p = 0.001$) (Table 8). For all three didactic strategies, we also found statistically significant partial correlations, indicating a weak correlation between pupils' perceptions of the didactic strategies and their academic performance. Higher-achieving pupils perceive a statistically significant increase in the presence of experiential ($\beta = 0.125$) and problem-based ($\beta = 0.093$) learning and a decrease in the presence of cross-curricular learning ($\beta = -0.091$). Among the statistically significant correlations obtained, the strongest was the correlation between learning performance and perception of research-based learning, which shows that a one-point increase in academic performance leads to a 0.05-point increase in perception of research-based learning. Similar predictive power applies to cross-curricular and problem-based learning. Pupils' academic performance in primary school did not emerge as an influential factor in perceptions of project-based and experiential learning.

Discussion

In our research, we found that teachers and pupils perceived problem-based and exploratory instruction, which are very similar, as the most used didactic strategies (Blažič et al., 2003). Jančič Hegediš and Hus (2019) also found in their study that teachers of Grades 4 and 5 most often incorporate problem-based and research-based learning into their teaching practice.

The presence of these strategies in pedagogical practice is gratifying, as they have a positive impact on the development of critical thinking and lifelong learning (Darhim et al., 2020; Ivanuš Grmek et al., 2009) and thus contribute to the performance of the important goal of education: to teach pupils to think and to become lifelong learners. In addition, independent problem-solving stimulates pupils' thought processes, increases the possibility of internalising knowledge, and thus contributes to better academic performance (Kozina & Vršnik Perše, 2015).

However, it should be noted that approaches that promote problem-solving are not universally effective. The use of certain didactic approaches alone does not necessarily have a positive impact on the quality of learning, as also explained by cognitive load theory. In the early stages of knowledge acquisition, didactic approaches based on self-discovery can be ineffective because they overload the pupil's working memory. In this case, guided approaches are more effective. It is important, too, to be aware that approaches that are effective for less proficient learners are not necessarily effective for more proficient learners (Hattie & Yates, 2014). Therefore, to realise all these benefits, it is essential to consider pupils' capacities (Blažič et al., 2003; Košir et al., 2020). In order to implement these strategies well, the teacher must have good knowledge of and respect for the backgrounds and abilities of the pupils, as well as the didactical competence to implement the strategies.

It should be noted that pupils rarely perceive the integration of these strategies in the classroom. Project-based learning was perceived by both teachers and pupils to be the least frequently used didactic strategy and was identified by Jančič Hegediš and Hus (2019) as the strategy that occurs least frequently in pedagogical practice. Project-based learning is characterised by pupils learning about an interdisciplinary topic, which is why it occurs mainly outside the regular classroom (Blažič et al., 2003; Ivanuš Grmek & Hus, 2006). In our opinion, this is why it is less widespread in pedagogical practice, as it requires networking with external experts, more detailed planning, and more time. Nevertheless, it is worth considering the possibilities of integrating project-based learning into teaching practice, as research has shown that it has a positive impact on pupils' motivation, autonomy, metacognitive skills, academic performance, and other important attributes (Gerhana et al., 2017; Lazić et al., 2021).

The less frequent integration of these didactic strategies into teaching practice is mainly attributed by teachers at all levels of education to a lack of time, too many classes, and poor matching of curricular content with the strategies (Jahan et al., 2016; Jančič Hegediš & Hus, 2019), and a high level of comfort with traditional approaches to teaching (Jahan et al., 2016). Teachers cite reasons related to their competence to implement different didactic strategies less frequently, which Jančič Hegediš and Hus (2019) link to the fact that it is easier to find reasons for not implementing active didactic strategies in one's own pedagogical practice in external factors rather than in one's own competence. This is why we believe that future teachers and practitioners need to strengthen and develop self-reflection skills that allow them to provide quality feedback and improve their performance as a result.

As pupils have few opportunities to acquire knowledge through active didactic strategies at the primary level of education, it is understandable that even at higher levels of education, they lack the necessary knowledge to participate actively in different didactic strategies and are consequently unwilling to do so, as confirmed by the results of the research conducted by Jahn et al. (2016).

The results of our study confirm the hypothesis that there are differences in teachers' and pupils' perceptions of didactic strategies. Statistically significant differences emerged for all didactic strategies, with teachers rating the integration of different strategies into their teaching practice higher than their pupils. As the responsibility for the quality of the educational process lies with the teachers, it was expected that they would give socially desirable answers. It could also be due to pupils being critical of the teacher's activities or, conversely, to the teacher not being critical of his or her own actions, but the repeated results, which generally show differences between teachers and pupils in this direction, suggest that pupils do not adequately perceive teachers' efforts. This has been pointed out in previous studies (Ivanuš Grmek et al., 2007; Javornik et al., 2008). This discrepancy is worrying, as it raises doubts about the adequacy of communication between teachers and pupils. This is why the identified pupil-teacher gap needs further research attention in the future.

An analysis of the relationship between perceptions of didactic strategies and pupils' learning performance in primary school showed a statistically significant relationship between academic performance and perceptions of experiential learning, cross-curricular and problem-based learning. Pupils with higher scores were more likely to report the presence of research- and problem-based learning. In contrast, higher-performing pupils perceived less cross-curricular teaching. These findings raise new questions and the need for further research. The reciprocal relationship between academic performance and teaching methods also deserves further attention. This raises new questions about strategies, forms, and methods of work in primary school practice and provides opportunities for future in-depth quantitative and qualitative empirical research.

Conclusion, Limitations and Further Research

International research shows the positive impact of active learning on pupil performance (Kozina & Vršnik Perše, 2015). It should be noted at this point that the use of certain didactic strategies alone does not necessarily contribute to better quality learning (Košir et al., 2020).

In this context, our research findings that open instruction is still not sufficiently embedded in pedagogical practice from the learners' perspective and that perceptions of strategies' use vary between learners and teachers warrant further research attention to explore the factors that influence the effective use of these strategies in teaching practice and to address the different judgements made by teachers and learners.

However, when interpreting the findings, it is important to bear in mind some of the limitations of the study. First, the limited set of five didactic strategies (problem-based learning, research-based learning, experiential learning, cross-curricular learning, and project-based learning) was analysed in this study. However, in the pedagogical practice of primary school education, it is also possible to predict other didactic strategies and approaches which may not have been recognised within the five studied didactical approaches in this study. Therefore, further studies should extend this studied set of didactic strategies to identify which approaches are used in primary school teaching practice.

Second, this study's findings are based on a monomethod research approach, which was based on quantitative interviews with pupils and teachers. A mixed methods research approach, which combines qualitative and quantitative research methods (Creswell, 2014), could provide a more in-depth and comprehensive insight into the issues at hand and increase the validity and reliability of the results obtained. This limitation does not detract from the credibility of the findings but rather suggests the need for further research and development monitoring of teaching practice in the research field, including qualitative approaches to research such as interviews and focus groups, and, above all, a complementary approach between the two methodologies.

The findings of our research and in-depth reflection on the reasons behind these findings can serve as a basis for teacher training and reflection on what today's teachers need to be able to implement didactic approaches in their teaching practice that will enable their pupils to acquire the highest quality and lasting knowledge. We can conclude from the above that knowledge and use of different didactic strategies alone is not enough to improve the learning process, as a quality learning process requires the broader concept of educational work to be taken into account with a heterogeneous group of learners.

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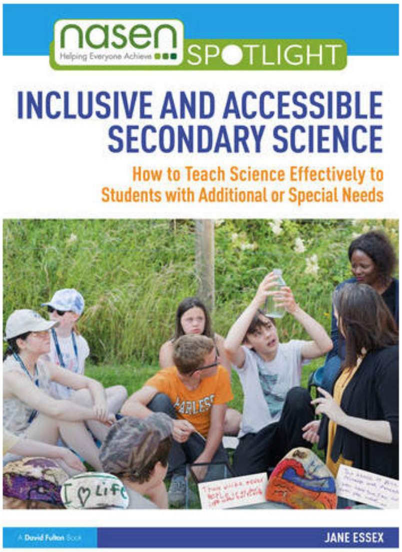
Jane Essex, *Inclusive and Accessible Secondary Science: How to Teach Science Effectively to Students with Additional or Special Needs*, Routledge, 2023; 133 pp.: ISBN: 978-1-00316-781-5

Reviewed by Elisabeth Hofer[1]



In her book *Inclusive and Accessible Secondary Science*, Jane Essex argues why science education is relevant and beneficial for all people and, therefore, should be accessible to all students, including those with specific or additional needs, even at the secondary level. She discusses the challenges students with learning difficulties encounter in secondary science education and addresses how teachers can counteract this, not only in terms of lesson planning and teaching but also regarding assessment. In so doing, Essex repeatedly refers to her experiences and teaching expertise resulting from the almost 40 years she worked as a science teacher and science teacher educator in England. The book is primarily aimed at science teachers or science teacher educators and thus repeatedly refers to specific teaching situations and instructional strategies. In addition, the readers are continually invited to reflect on their beliefs, perspectives, and teaching contexts, which is encouraged by guiding questions.

Inclusive and Accessible Secondary Science can be roughly divided into two main parts: In the theoretical part, fundamental considerations on the raison d'être of inclusive science education are explained, and the underlying concepts from the fields of pedagogy, science didactics and learning psychology are elaborated, including findings from empirical research. In the practical part, the book provides insight into specific teaching sequences on selected subject

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areas inherent to the first years of learning science in secondary schools and lists some sources recommended for support or further reading.

In her considerations, Essex tirelessly advocates the importance of and the right to access secondary science education. She emphasises the following aspects (among others) related to the perspective of individual students, secondary science teachers, the school system, and society.

Recognising that learning science has universal benefits. Learning science is not limited to preparing individuals for professional, scientific careers. Dealing with science contexts, concepts, and practices equips students with critical thinking skills, problem-solving abilities, and a deeper understanding of the world around them. These skills are universally valuable and contribute to a more informed and engaged citizenship in a society increasingly influenced by innovations in science and technology. With this in mind, Essex advocates scientific literacy for all (Roberts & Bybee, 2014) and calls on society, the educational system, and individual teachers to fulfil their obligation to allow students to acquire this literacy. First and foremost, not only because all people have the right to access quality and equal education, for legal reasons alone, but also because science for all addresses multiple challenges of today's society, such as a shortage of skilled workers while unemployment is simultaneously prevalent among people with learning difficulties or special needs. Beyond that, a considerable part of society is sceptical about science and research, resulting in uninformed consumer decisions, impeding sustainable development.

Acknowledging the potential of diversity for science education and science in general. The historical elitism and exclusionary practices associated with science have perpetuated stereotypes and hindered diversity in both the field of science and science education. By making science teaching (more) inclusive, Essex argues, teachers can challenge these entrenched norms, promoting diversity and breaking down barriers that have long limited access based on socio-economic status, gender, ethnicity, and – in particular – students' learning preconditions. In Essex's opinion, the cultural trappings embedded in scientific practices, such as exclusive language and inaccessible jargon, are not essential for acquiring scientific literacy. However, they disadvantage and categorically exclude students with lower literacy and communication skills. By embracing inclusive approaches to teaching, science education can shed these barriers, making scientific knowledge more accessible and relevant to students with diverse backgrounds and needs. In so doing, science education might contribute to broader societal goals of promoting equity and social justice. It ensures that opportunities to engage with and contribute to scientific knowledge are accessible to everyone, cultivating future generations of scientifically literate individuals who can participate in society in various capacities.

Addressing barriers to science and science education (for students with learning difficulties). The existing science curriculum and pedagogical approaches often create obstacles for students with learning difficulties. Essex states that she is 'conscious of the fact that many teachers […] will not feel able to modify *what* they teach. Despite this, they can still adapt the way in which they teach it […]' (p. 15). Accordingly, she promotes providing various learning resources, incorporating real-world examples that resonate with students from various backgrounds, and fostering a classroom environment that encourages collaboration and respect for diverse perspectives. Recognising and addressing existing barriers may contribute to ensuring that diverse learning styles and abilities are accommodated, allowing all students to participate. Following Essex, students' participation in science education is important for various reasons, for example, for students' enjoyment, personal development and empowerment, their development of science-specific and transferable skills, and their ability to participate in today's society.

After having introduced the theoretical framework regarding inclusive science education, Essex explores why students 'with learning difficulties underachieve in science' and makes suggestions on 'how […] teachers [can] mitigate this' (p. 15). Above all, two well-known theories, namely the levels of cognitive development defined by Piaget and Bloom's taxonomy of cognitive processes, are referred to as the basis for this. Even though these theories may be helpful in identifying the demands of tasks and activities when learning science, they are, unfortunately, primarily related to the cognitive domain of learning science. This analysis does not fully meet the idea of inclusive science education (as presented in previous sections) in that it neglects social, cultural, emotional, and physical factors of learning. By not only naming the other two less well-known domains of Bloom's taxonomy (affective, psychomotor) but also integrating them, a broader perspective could have been taken. Nevertheless, including additional models (e.g., SOLO taxonomy; Biggs & Collis, 1982) and findings from empirical studies, Essex clearly shows that the demands of learning science are often overwhelming not only for students with additional or special needs but also for many others. To counteract this, Essex presents the suggestions of the CASE (Cognitive Acceleration in Science Education; Shayer & Adey, 2002) project to foster students' development of formal thinking, drawing on experiences from her teaching. Further, she figures out four ways in which those with learning difficulties may differ from their peers: executive functions, functional skills, psycho-social characteristics, and experimental and investigative skills. It is described comprehensively how these four aspects – that are no longer limited to the cognitive domain – can manifest themselves and influence students' learning on the one hand, and how teachers can create science lessons and teaching material that addresses these aspects, on the other hand. By presenting concrete examples, teachers can develop ideas, for example, reducing students' cognitive load, enhancing materials' readability, or creating learning opportunities that allow for differentiation. However, focusing on 'students' challenges' to differentiate between 'students with learning difficulties' and 'their peers' is also at risk of fostering a deficit-oriented and categorising perspective on students and their learning. This sensitive balancing act between addressing students and their individual needs and systematically attributing 'diagnoses' is supported to some extent by the reflective questions. In some of these questions, the barriers to learning are located in the system or learning object (e.g., curriculum, technical language, abstraction, mathematisation) rather than in the students, and teachers are encouraged to reflect on how these barriers could be reduced, minimised, or eliminated by adapting material and instructional strategies (cf. Stinken-Rösner et al., 2020).

One of the distinguishing features of *Inclusive and accessible secondary science* is the section on assessment, which is often disregarded in the context of inclusive education. Essex does not so much focus on specific aspects of 'inclusive assessment' but rather on how to create assessment that covers a broad range of goals aimed for in science education. By opening assessment to different aspects of learning science, the learning outcomes of students with diverse backgrounds and needs – and in particular of students with learning difficulties – can be captured. Essex argues that established assessment techniques, such as typical tests, need to be changed or at least extended by various approaches as students 'who do not do well on such tests should not be assumed not to have learnt, but rather not to have learnt the skills required to bring about success in tests' (p. 61). She advocates aligning assessment with the 'real' teaching intentions, not only those formulated by the curriculum, removing unnecessary barriers from assessment tasks and integrating open-ended questions that allow for creativity and various ways of answering.

The practical section, which forms the back part of the book, consists of concrete teaching sequences related to nine subject areas (e.g., matter, plants, earth, and space). Each of the presented sequences comprises up to eight lessons and is described in terms of learning intentions, the relevance of the topic and the addressed knowledge and skills, the applied instructional strategies, and students' activities and learning opportunities. In so doing, inclusive approaches are discussed by referring to parts of the used teaching materials in order to illustrate how teachers can increase the accessibility of their science lessons. The presented examples serve as great suggestions for teachers and their teaching practice. Even though the sequences are clearly based on the principles set out in the theoretical section, it is not clear from the practical section whether or in what form the 'effectiveness' of the presented lessons has been investigated. It can, therefore, be assumed that the subtitle of the book, *How to Teach Science Effectively to Students with Additional or Special Needs*, refers to the theoretical framework, including findings from empirical studies in the first part of the book, whereas the practical part is primarily based on the author's own experiences from many years of professional practice.

In *Inclusive and Accessible Secondary Science,* Jane Essex provides a comprehensive argument for the importance of making science education accessible to all learners, particularly to those with specific or additional needs. Through a blend of theoretical discussion and practical insights drawn from her extensive experience, Essex highlights the universal benefits of science education, emphasising its role in fostering critical thinking, problem-solving skills, and a deeper understanding of the world. Essex addresses the challenges faced by students with learning difficulties in secondary science education, offering strategies for teachers to mitigate these challenges in lesson planning, teaching, and assessment. She advocates for inclusive teaching practices that recognise and embrace the diversity of learners, challenging traditional norms and promoting equity and social justice in science education. Overall, *Inclusive and Accessible Secondary Science* serves as a valuable resource for science teachers and science teacher educators, offering both theoretical insights and practical guidance for creating inclusive learning environments where all students can thrive in their science-specific and social pursuits.

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