DOI: https://doi.org/10.26529/cepsj.1707

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

1 *Corresponding Author. San Diego State University, San Diego, USA; and Science Foundation Ireland Research Centre for Pharmaceuticals (SSPC), University of Limerick, Limerick, Ireland; gguralp@sdsu.edu.

2 Science Foundation Ireland Research Centre for Pharmaceuticals (SSPC), University of Limerick, Limerick, Ireland.

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 under-explored. 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 ethno-cultural 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

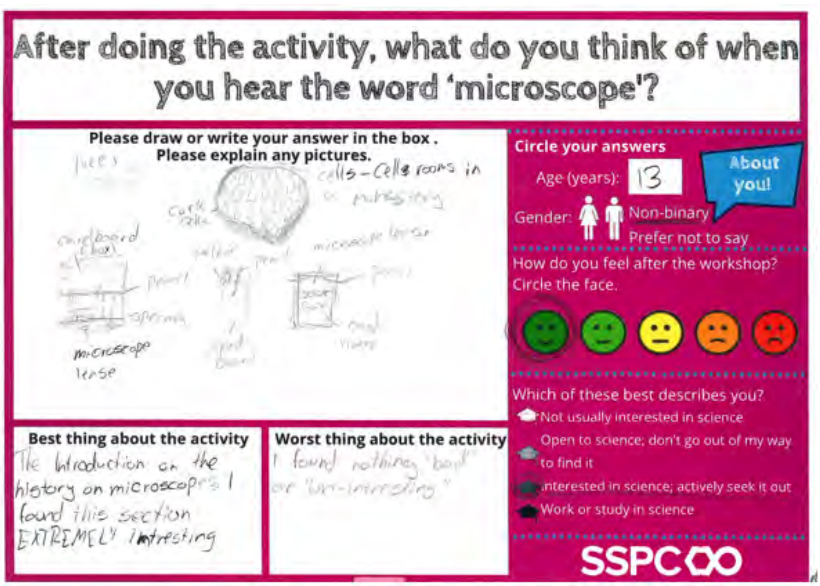
8 The data for 'Interest for the subject' and 'Motivation' items can be found in the Tables 5 and 6 respectively, in the Appendix.

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.

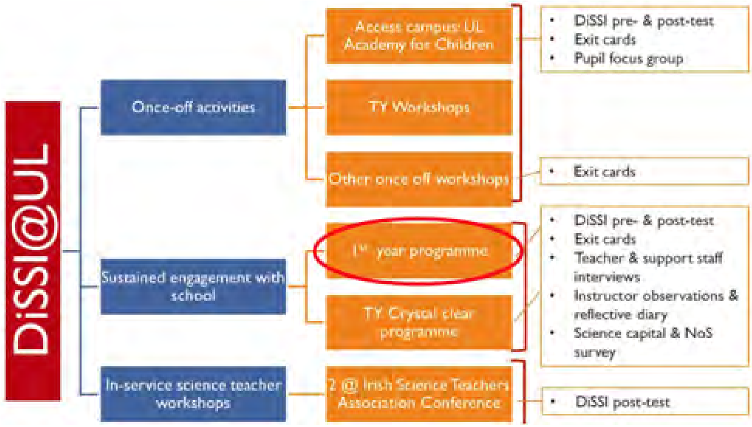
Three semi-structured open-ended teacher interviews were conducted at the end of the programme (two teacher interviews and one interview with the Special Educational Needs teacher who supported the teaching). The teacher interview questions were developed by the research team with the aim of eliciting 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.

Acknowledgement

This research was part of the project 'DiSSI – Diversity in Science towards Social Inclusion – Non-formal Education in Science for Students' Diversity', which is co-funded by the Erasmus+ Programme of the European Union under the grant number 612103-EPP-1_2019-1-DE-EPPKA3-IPI-SOC-IN. We would like to thank the European Union for its financial support. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein. The authors would like to acknowledge funding from the Science Foundation Ireland (SFI) through SSPC, the SFI Research Centre for Pharmaceuticals, grant number 12/RC/2275_P2, which is co-funded under the European Regional Development Fund. We would like to thank the two anonymous reviewers for their valuable suggestions and comments. The authors would also like to acknowledge all the participating teachers and students in this project for their collaboration and contributions to the project, and for their meaningful engagement with the research team.

References

Acquah, E. O., Szelei, N., & Katz, H. T. (2020). Using modelling to make culturally responsive pedagogy explicit in preservice teacher education in Finland. *British Educational Research Journal*, *46*(1), 122–139.

AlShebli, B. K., Rahwan, T., & Woon, W. L. (2018). The preeminence of ethnic diversity in scientific collaboration. *Nature Communications*, *9*(1), 5163.

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922– 948.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). "Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, *96*(6), 967–989.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*(5), 564–582.

Avraamidou, L. (2020). Science identity as a landscape of becoming: rethinking recognition and emotions through an intersectionality lens. *Cultural Studies of Science Education*, *15*(2), 323–345.

Avraamidou, L. & Schwartz, R. (2021). Who aspires to be a scientist/who is allowed in science? science identity as a lens to exploring the political dimension of the nature of science. *Cultural Studies of Science Education*, *16*(2), 337–344.

Barton, A. C., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal*, *50*(1), 37–75.

Barton, A. C. & Tan, E. (2018). A longitudinal study of equity-oriented stem-rich making among youth from historically marginalized communities. *American Educational Research Journal*, *55*(4), 761–800.

Borg, W. R. & Gall, M. D. (1983). *Educational Research An Introduction* (4th ed.). Longman.

Bourdieu, P. (1990). *The Logic of Practice*. Stanford University Press.

Bourdieu, P. & Passeron, J. C. (1990). *Reproduction in Education, Society and Culture*. Published in association with Theory, Culture & Society. SAGE Publications.

Calabrese Barton, A., Greenberg, D., Kim, W. J., Brien, S., Roby, R., Balzer, M., Turner, C., & Archer, L. (2021). Disruptive moments as opportunities towards justice-oriented pedagogical practice in informal science learning. *Science Education*, *105*(6), 1229–1251.

Carlone, H. B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218.

Carter, L., Weinstein, M., & Bencze, L. (2017). Biopolitics and science education. *Cultural Studies of Science Education, 12*(4), 761–767.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*(2), 255–265.

Chen, A., Darst, P. W., & Pangrazi, R. P. (2001). An examination of situational interest and its sources. *British Journal of Educational Psychology*, *71*(3), 383–400.

Chen, S. & Wei, B. (2022). Development and validation of an instrument to measure high school students' science identity in science learning. *Research in Science Education*, *52*(1), 111–126.

Chzhen, Y. (2023, July 23). *How lockdown highlighted educational inequality in Ireland – new research*. The Conversation. https://theconversation.com/how-lockdown-highlighted-educational-inequality-in-ireland-new-research-177413

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297-298.

Cohen, L., Manion, L. & Morrison, K. (2007). *Research Methods in Education* (6th Ed.). Routledge.

Considine, J.R., Mihalick, J.E., Mogi-Hein, Y.R., Penick-Parks, M.W. & Van Auken, P.M. (2017). How Do You Achieve Inclusive Excellence in the Classroom?. *Teaching and Learning*, *2017*(151), 171-187.

Cooper, G. & Berry, A. (2020). Demographic predictors of senior secondary participation in biology, physics, chemistry and earth/space sciences: students' access to cultural, social and science capital. *International Journal of Science Education*, *42*(1), 151–166.

Cooper, G., Berry, A., & Baglin, J. (2020). Demographic predictors of students' science participation over the age of 16: An Australian case study. *Research in Science Education*, *50*(1), 361–373.

Creghan, C., & Adair-Creghan, K. (2015). The Positive Impact of Project-Based Learning on Attendance of an Economically Disadvantaged Student Population: A Multiyear Study. *Interdisciplinary Journal of Problem-Based Learning, 9*(2).

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *The University of Chicago Legal*

Forum, *140*, 139–167.

Crenshaw, K. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, *43*(6), 1241–1299.

Cuevas, P., Lee, O., Hart, J. & Deaktor, R. (2005), Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, *42*, 337–357.

Dagher, Zoubeida R. & Erduran, Sibel (2016). Reconceptualizing the Nature of Science for Science Education. *Science & Education, 25*(1–2), 147-164.

DeWitt, J. & Archer, L. (2015). Who Aspires to a Science Career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192.

DeWitt, J., Archer, L., & Mau, A. (2016). Dimensions of science capital: exploring its potential for understanding students' science participation. *International Journal of Science Education*, *38*(16), 2431–2449.

Erduran, S. & Wong, S. L. (2013). Science Curriculum Reform on 'Scientific Literacy for All' Across National Contexts: Case Studies of Curricula from England & Wales and Hong Kong. In Mansour, N. and Wegerif, R. (Eds.). *Science Education for Diversity*, 179–201. Springer.

Ferguson, S. L. & Lezotte, S. M. (2020). Exploring the state of science stereotypes: Systematic review and meta-analysis of the draw-a-scientist checklist. *School Science and Mathematics*, *120*(1), 55–65.

Fowler, K., Windschitl, M., & Richards, J. (2019). Exit tickets: Understanding students, adapting instruction, and addressing equity. *The Science Teacher*, *86*(8), 18–26.

Garner, N., Hayes, S. M., and Eilks, I. (2014). Linking formal and non-formal learning in science education a reflection from two cases. *SISYPHUS journal of education*, *2*(2), 10–31.

Gay, G. (2002). Culturally responsive teaching in special education for ethnically diverse students: Setting the stage, *International Journal of Qualitative Studies in Education*, *15*(6), 613–629.

Godec, S., King, H. & Archer, L. (2017). *The Science Capital Teaching Approach: engaging students with science, promoting social justice.* University College London.

Gorard, S. & See, B. H. (2009). The impact of socioeconomic status on participation and attainment in science. *Studies in Science Education*, *45*(1), 93–129.

Haase, T. & Pratschke, J. (2023, July 23). *The 2016 Pobal HP deprivation index*. Trutz Haase. http://trutzhaase.eu/deprivation-index/the-2016-pobal-hp-deprivation-index-for-small-areas/

Harper, A. & Kayumova, S. (2023). Invisible multilingual black and brown girls: Raciolinguistic narratives of identity in science education. *Journal of Research in Science Teaching*, *60*(5), 1092–1124.

Haynes, A., Joyce, S., & Schweppe, J. (2021). The significance of the declaration of ethnic minority status for Irish travellers. *Nationalities Papers*, *49*(2), 270-288.

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education, 28*, 87–112.

Holmegaard, H. T. & Archer, L., editors (2023). *Science Identities*. Contributions from Science Education Research. Springer International Publishing.

Hong, L. & Page, S. E. (2004). Groups of diverse problem solvers can outperform groups of high-ability problem solvers. *Proceedings of the National Academy of Sciences*, *101*(46), 16385–16389.

Jones, T. R. & Burrell, S. (2022). Present in class yet absent in science: The individual and societal impact of inequitable science instruction and challenge to improve science instruction. *Science Education*, *106*(5), 1032–1053.

Kayumova, S. & Dou, R. (2022). Equity and justice in science education: Toward a pluriverse of multiple identities and onto-epistemologies. *Science Education*, *106*(5), 1097–1117.

Kayumova, S., McGuire, C. J., & Cardello, S. (2019). From empowerment to response-ability: rethinking socio-spatial, environmental justice, and nature-culture binaries in the context of stem education. *Cultural Studies of Science Education*, *14*(1), 205–229.

Keller, L., Lüdtke, O., Preckel, F., & Brunner, M. (2023). Educational inequalities at the intersection of multiple social categories: An introduction and systematic review of the multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) approach. *Educational Psychology Review*, *35*(1), 31.

Kenny, N., McCoy, S., & Mihut, G. (2020). Special education reforms in Ireland: changing systems, changing schools. *International Journal of Inclusive Education*, 1–20.

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the stem career interest survey (stem-cis). *Research in Science Education*, *44*(3), 461–481.

Lee, O. & Luykx, A. (2006). *Science Education and Student Diversity: Synthesis and Research Agenda*. Cambridge University Press.

Mansour, N. & Wegerif, R. (Eds.). (2013). *Science Education for Diversity*. Springer Dordrecht.

Marosi, N., Avraamidou, L., & Galani, L. (2021). Culturally relevant pedagogies in science education as a response to global migration. *SN Social Sciences*, *1*(6), 147.

McCoy, S., Byrne, D., & O'Connor, P. (2022). Gender stereotyping in mothers' and teachers' perceptions of boys' and girls' mathematics performance in Ireland. *Oxford Review of Education*, *48*(3), 341–363.

McHugh, M., Hayes, S., Tajber, L., & Ryan, L. (2022). Medicine maker: An outreach activity for pharmaceutical manufacturing and health literacy. *Journal of Chemical Education*, *99*(3), 1231–1237.

McManus, B., Dwyer, A., Childs, P., Broggy, J. & Mccormack, O. (2015). Teaching Enquiry with mysteries incorporated: the benefits of involving pre-service teachers. *LUMAT International Journal on Math Science and Technology Education*, *3*(4), 512–528.

Mihut, G., McCoy, S., & Maître, B. (2022). A capability approach to understanding academic and socio-emotional outcomes of students with special educational needs in Ireland. *Oxford Review of Education*, *48*(3), 271–288.

OECD (2012). *Recognition of Non-formal and Informal Learning - Home*. OECD. https://www.oecd.org/education/skills-beyond-school/recognitionofnon-formalandinformallearning-home.htm

OECD/PISA (2009). *PISA 2006 Technical Report*. OECD Publishing.

Rennie, L. J. (2007). Learning science outside of school. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research and science education* (pp. 125–167). Lawrence Erlbaum.

Ryan, R. M. & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 6878.

Saldana, J. M. (2015). *The coding manual for qualitative researchers* (3rd ed.). SAGE Publications.

Sharpe, R. & Abrahams, I. (2020). Secondary school students' attitudes to practical work in biology, chemistry and physics in England. *Research in Science & Technological Education, 38*(1), 84–104.

Smyth, E., McCoy, S., & Kingston, G. (2015). *'Learning from the evaluation of DEIS': Research Series (39)*. Economic and Social Research Institute. https://www.esri.ie/system/files/publications/RS39.pdf

Smyth, E. (2020). Shaping educational expectations: the perspectives of 13-year-olds and their parents. *Educational Review*, *72*(2), 173–195.

Snětinová, M., Kácovský, P., & Machalická, J. (2018). Hands-On Experiments in the Interactive Physics Laboratory: Students' Intrinsic Motivation and Understanding. *Center for Educational Policy Studies Journal*, *8*(1), 55-75. https://doi.org/10.26529/cepsj.319

Summerlee, A.J.S. (2018). Inquiry-based learning: A socially just approach to higher education. *Journal of Human Behavior in the Social Environment, 28*(4), 406–418.

Tobin, K., Seiler, G., & Smith, M. W. (1999). Educating science teachers for the sociocultural diversity of urban schools. *Research in Science Education*, *29*(1), 69–88.

White, A. M., DeCuir-Gunby, J. T., & Kim, S. (2019). A mixed methods exploration of the relationships between the racial identity, science identity, science self-efficacy, and science achievement of African American students at HBCUs. *Contemporary Educational Psychology*, *57*, 54–71.

Wright, G. W. & Delgado, C. (2023). Generating a framework for gender and sexual diversity-inclusive stem education. *Science Education, 107*(3), 713–740.

Zhang, L. (2016). Is Inquiry-Based Science Teaching Worth the Effort?. *Science & Education, 25*, 897–915.

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

Genco Guralp, PhD, is an assistant professor in philosophy at San Diego State University, and a postdoctoral researcher at SSPC, the Science Foundation Ireland Research Centre for Pharmaceuticals, at the University of Limerick. His post-doctoral work is on Science Education and Public Engagement in Science through the ERASMUS+ DiSSI project. His research areas include the history and philosophy of science, philosophy of cosmology, philosophy of physics, and the historical epistemology of science. His recent work focuses on science studies and the sociology of science in the context of STEM education and public engagement with science.

Martin McHugh, PhD, is a Projects and Public Engagement Officer at SSPC. He is a former science and biology teacher and in 2017 completed a PhD investigating the impact of video technology on student interest and engagement throughout secondary schools in Ireland. Currently, Martin develops medicine and health-themed public engagement activities for diverse public groups, and he is active in collaborative research investigations into the impact of informal and non-formal learning environments on participants.

Sarah Hayes, PhD, is the Chief Operations Officer at SSPC, the SFI Research Centre for Pharmaceuticals. Sarah is a former physics and chemistry teacher and completed her PhD in science education. Currently, Sarah works with a broad number of stakeholders including academic, industry, and societal partners to enhance collaboration and develop impactful public engagement projects. She conducts research in the area of informal and non-formal learning and engagement in science.