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# TINKERING AS AN INCLUSIVE APPROACH FOR BUILDING STEM IDENTITY AND SUPPORTING STUDENTS FACING DISADVANTAGE OR WITH LOW SCIENCE CAPITAL

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CONSIDERATIONS FROM A REFLECTIVE PRACTICE EXPERIENCE WITH TEACHERS



WITH THE SUPPORT OF ERASMUS+  
PROGRAMME OF THE EUROPEAN UNION



**Tinkering as an inclusive approach for building STEM identity and supporting students facing disadvantage or with low science capital: Considerations from a reflective practice experience with teachers**  
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PROJECT COORDINATOR

PARTNER INSTITUTIONS

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This work is being made possible through the support, commitment, energy, enthusiasm, ideas and action of the partners of the Tinkering Project and through the valuable cooperation and enthusiasm of the teachers who participated to the reflective practice experience in each country.

A special acknowledgement goes to the Tinkering Studio of the Exploratorium of San Francisco, expert advisor to this project, for their collaboration and support.

The photos included in this document are from the activities carried out in collaboration between the partner institutions and the schools. In particular the photos show activities at MUST; NEMO Science Museum (credits @Digidaan) and NOESIS.

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A young person with dark hair, wearing a white school uniform with a dark tie and a circular logo on the chest, is focused on working on a cardboard box. They are holding a piece of paper and a thin rod, possibly a straw, near the box. The scene is set in a classroom or workshop, with a desk and other items visible in the background. The entire image has a blue color cast. A yellow rectangular box is overlaid on the lower left side of the image, containing the text 'INTRODUCTION'.

## INTRODUCTION

# INTRODUCTION

## PROJECT CONTEXT

From 2017 to 2020, the Erasmus+ -funded project 'Tinkering EU: Building Science Capital for ALL'<sup>1</sup> has brought together science education practitioners from across the informal and formal education sectors to explore the potential benefits of using Tinkering pedagogy with young people facing economic, social and cultural disadvantage with the aim of strengthening their STEM (Science, Technology, Engineering and Maths) identity and helping them to build transferable 21st century skills. The project emerged from the following challenges facing contemporary global society:

**1. Creating education systems that support active citizenship:** Modern societies face many contemporary challenges including: issues relating to cultural and social inclusion; access to wellbeing, health and education opportunities; and democratic participation. Robust, cohesive communities, capable of responding effectively to these challenges require reflective, informed citizens equipped with skills such as creativity, innovation, critical thinking, and entrepreneurship (the so-called 21st century skills). Active citizens are those who are highly motivated, socially engaged, and able to turn creative ideas into action and find innovative solutions to new problems. Contemporary society therefore needs education systems that can build the knowledge and skills necessary for creating active citizens.

**2. How to build scientific literacy for all citizens:** Scientific literacy is becoming indispensable as global society looks to science and technology to solve contemporary problems. Traditionally, schools have been entrusted with the responsibility of producing a scientifically literate population, but formal approaches to science education still fail to engage many young people and STEM skills gaps are widening in Europe, indicating that schools cannot bear the task alone.

**3. How to increase and widen participation in STEM learning:** In school, this can be particularly challenging for young people with learning difficulties, poor school performance and for those from socially and culturally marginalised groups. International surveys reveal disaffection and poor engagement with school practice for disadvantaged young people, and even more so in science, with worrying potential consequences for employability and social participation.

To respond to the above challenges, especially for those facing disadvantage, this project has aimed to help support school practice by adopting new approaches to STEM education that favour student-centred teaching and learning pedagogies. This project has responded to the above needs by investing in Tinkering as a powerful way to develop a learner-centred culture both in and out of school and to develop 21st century skills which support active citizenship, employability, and social inclusion.

<sup>1</sup> 'Tinkering EU: Building Science Capital for ALL' is a strategic partnership funded by the Erasmus+ Programme of the European Union. REF. 2017-1-IT02-KA201-036513. <http://www.museoscienza.it/tinkering-eu2/default.asp>



The project has built upon learning gained from its predecessor project 'Tinkering: Contemporary Education for Innovators of Tomorrow'<sup>2</sup> which introduced Tinkering in the European context, developed and implemented new Tinkering activities to enrich the fields of formal and informal science education, and supported the development of 21st century skills for young people and adults.

As well as building upon knowledge gained from the first project around successful implementation of Tinkering activities with diverse audiences and working with schools to promote uptake, 'Tinkering EU: Building Science Capital for All' has also been informed by educational research in the area of 'science capital'. This research is helping to explain why some students feel more at home with STEM learning in school, and why some students are more likely to want to pursue STEM learning than others. Outside influences – such as having a network of people to talk with about science, parents who work in STEM-related jobs, and trips to science museums – all interact to shape whether a young person will aspire to participate in STEM (Archer, Dawson, DeWitt, Godec, et al., 2015; Archer, Dawson, DeWitt, Seakins, et al., 2015; Archer et al., 2010, 2012, 2013; DeWitt et al., 2016; DeWitt & Archer, 2015; Godec et al., 2017). Research has shown that students with high levels of science capital (that is, students who have access to science resources in their lives outside of school) tend to identify with and aspire to participate in STEM, both in school and beyond. On the other hand, students with fewer STEM opportunities or limited access to resources outside

of school (with relatively lower levels of science capital) are more likely to feel disconnected with STEM education because it does not resonate with things they are doing or how they see it connected with their wider lives (DeWitt et al., 2016; DeWitt & Archer, 2015). In this context, the project used Tinkering pedagogy to create a bridging point between a learner's personal interests and experiences and a broad range of possible learning outcomes.

This document summarises the impact of the project through the description of the work carried out over three years which brought together museum educators and teachers to develop their practice and explore how Tinkering pedagogy could be used to develop more engaging, inclusive and equitable STEM learning experiences for learners facing educational, social, cultural or economic disadvantage.

The project activities were designed to enrich the practice of teachers working in schools with high numbers of students facing disadvantage and to increase their knowledge and understanding of Tinkering pedagogy, especially about how this could support inclusion in STEM learning at school. At the same time, the project designed and implemented a reflective practice process involving the participating schools, aiming to understand in more depth the potential impact of using a Tinkering approach with students facing disadvantage, who are likely to have relatively low levels of science capital. Using tools specifically designed to help teachers observe their students taking part in Tinkering activities and then

<sup>2</sup> Tinkering: Contemporary Education for Innovators of Tomorrow' is a strategic partnership funded by the Erasmus+ Programme of the European Union. REF. 2014-1-IT-02-KA200-003510. <http://www.museoscienza.it/tinkering-eu/default.asp>



reflect on these observations in relation to their practice, we were able to gain insights into such potential impact. **Indeed, teachers told us that Tinkering pedagogy can foster a more inclusive approach to STEM learning for all students, and particularly those facing disadvantage in STEM learning with low levels of science capital.** The findings emerging from the analysis of the reflective practice experience are discussed in more depth in sections 3 and 4.

## DOCUMENT OVERVIEW

**Section 1** describes the evolution of the collaborative work with schools, including the project methodology, and information about recruiting and working with the participating teachers and schools who met the target criteria for the project.

**Section 2** presents the tools created to support teachers to observe the broad-ranging learning outcomes that Tinkering experiences can elicit, as well as to reflect on the experience in relation to their individual students and their own pedagogical practice. It also outlines how this information, gathered from the participating teachers, was analysed in order to gain insights into the impact of the project work strands in relation to the key aims of the project.

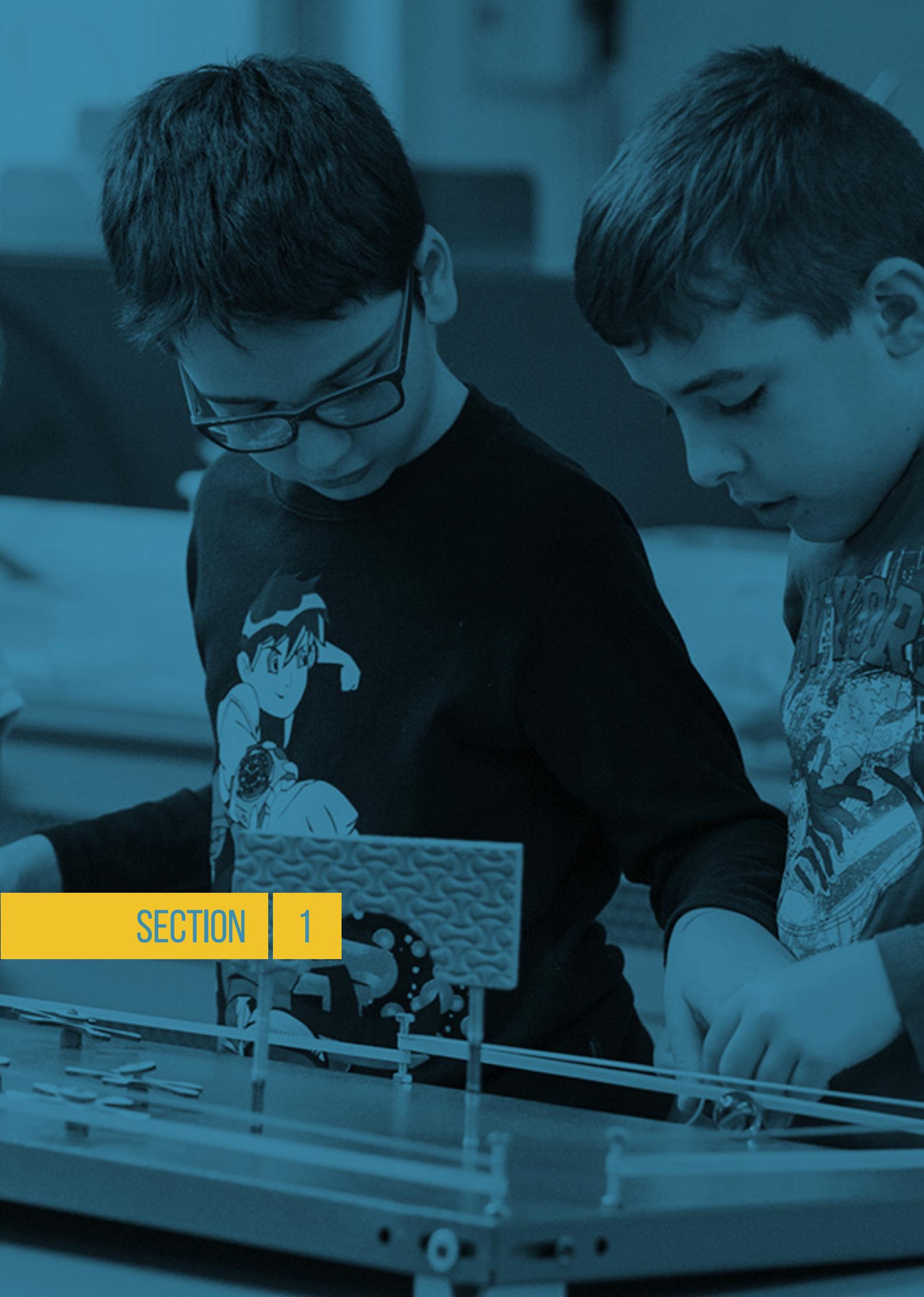
**Section 3** presents and discusses the findings of the evaluation work of the project which has explored the benefits of Tinkering pedagogy for increasing inclusion in STEM learning, as well as how the experience of taking part in this project may have influenced the teachers' own practice in their classrooms and schools.

**Section 4** provides a summary of the key findings from the project that have implications for future work in this area using Tinkering pedagogy as part of a widening participation and social justice agenda to create more equitable and inclusive STEM learning approaches for all learners, but particularly for those facing disadvantage.

This is the final output of 'Tinkering EU: Building Science Capital for All'. It brings together three years of work that started with theoretical considerations regarding the relationship between Tinkering as a pedagogical approach, students' individual science capital and inclusive STEM teaching approaches, continued with teacher training and testing of activities with students in each country, to end up with a specifically-designed reflective practice process that offered structured insights on how Tinkering is and can be integrated into school practice.

Supporting our arguments – as well as any recommendations of activities or tools – about the potential of Tinkering to increase science capital with empirical data and teachers' own reflections has been considered fundamental for the objective of this project. Such empirical data back our insistence for pedagogies that help improve learning in science and contribute to developing 21st Century skills: creativity, innovation, entrepreneurship, critical thinking.

At the same time, the tools used for observation and reflection, although specifically designed for this project, can indicate ways for informal and formal educators to delve deeper into the constituent elements and dynamics of pedagogy and their students' learning experience.



SECTION

1

# 1

## PROJECT METHODS OVERVIEW

### 1.1

#### CREATING THE BASIS FOR JOINT WORK: RECRUITMENT OF TARGET SCHOOLS AND TEACHER AMBASSADORS

The project work focused on schools (both teachers and students) from disadvantaged communities. An overarching project aim was to contribute to the improvement of school practice through the application of Tinkering pedagogy in order to develop more inclusive STEM learning experiences for students facing disadvantage whilst enabling teachers to explore the benefits of the approach for their students and think about it in relation to their own practice.

To select the most suitable participants for the project, the partner institutions<sup>3</sup> surveyed disadvantaged groups in their community, scrutinised local or national indications on this issue and identified schools that could most benefit from this collaboration. The target groups and recruitment methods for each partner are summarised in table 1.

Each partner identified and recruited 30 teachers from schools with high proportions of students facing disadvantage in one or more of the following areas:

- Educational disadvantage (for example because of learning difficulties and/or low school performance).
- Cultural disadvantage (for example, students from ethnic minority groups, non-native speakers and students with cultural inclusion difficulties, including migrant groups).
- Social and economic disadvantage (for example students from economically deprived areas with parents who are unemployed or on low incomes).

<sup>3</sup> Commencing in September 2017, the project involved six European science museums and science centres as partners: Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci (MUST), Italy (project coordinator); NEMO Science Museum, The Netherlands; Science Gallery Dublin (SGD), Ireland; CosmoCaixa, Spain; ScienceCentre-Netzwerk (SCN), Austria; Noesis, Greece.

**TABLE 1**  
**RECRUITMENT METHODS FOR EACH PARTNER INSTITUTION**

PARTNER	MAIN DISADVANTAGE TARGETED	IDENTIFICATION AND RECRUITMENT METHOD
<p>MUSEO NAZIONALE DELLA SCIENZA E DELLA TECNOLOGIA LEONARDO DA VINCI</p> <p>Italy</p>	<p>i) Educational poverty.</p> <p>ii) Schools from communities with social disadvantage.</p>	<ul style="list-style-type: none"> <li>Teachers were selected among those of Tinkering (for example those who participated in professional development courses organised by the Museum) and whose school also fitted the criteria of disadvantage according to the local School Authority indications. These were teachers of different disciplines coming from primary and junior high schools.</li> </ul>
<p>NEMO SCIENCE MUSEUM</p> <p>The Netherlands</p>	<p>i) Students from low-income families.</p> <p>ii) Students from migrant and refugee families, many of whom have low levels of Dutch language and or cultural inclusion difficulties.</p>	<ul style="list-style-type: none"> <li>Used national data to identify schools with higher levels of students on lower incomes and/or Dutch as a second language.</li> <li>Used national data to identify deprived areas with a high level of outflow of residents.</li> <li>Offered small-scale training events at a second site closer to some of the regional schools to reduce transport costs.</li> </ul>
<p>SCIENCE GALLERY DUBLIN</p> <p>Ireland</p>	<p>Students attending schools that are traditionally underrepresented in Irish higher education institutions. This includes students from areas of lower socioeconomic status, migrant families and from rural Irish backgrounds.</p>	<ul style="list-style-type: none"> <li>Used national data from the government Department of Education to identify schools linked with a DEIS (Delivering Equity of Opportunity in Schools) and rural status.</li> <li>Worked with Trinity College, Dublin to recruit through their Trinity 'Access21' widening participation programme.</li> <li>Offered a tour of the gallery alongside Tinkering workshop and further teacher training/resources.</li> </ul>
<p>COSMOCAIXA</p> <p>Spain</p>	<p>i) Students with socioeconomic disadvantages from schools at risk of exclusion (primary schools with a high number of students with socioeconomic disadvantages and/or cultural inclusion difficulties) and 'UEC' (Compulsory Secondary Education and Inclusive Education Units).</p> <p>ii) Students from migrant and refugee families, many of whom have low levels of Spanish language.</p>	<ul style="list-style-type: none"> <li>Identification of schools and institutes that belong to the categories defined in the 'Main disadvantage targeted' column which included schools with students at risk of exclusion.</li> <li>Offered small-scale trainings for the teachers in Tinkering activities at CosmoCaixa.</li> </ul>
<p>SCIENCECENTRE-NETZWERK</p> <p>Austria</p>	<p>i) Students from lower income families.</p> <p>ii) Students from migrant and refugee families, many of whom have low levels of German language and or cultural inclusion difficulties.</p>	<ul style="list-style-type: none"> <li>Targeted NMS schools (New Secondary Schools) less likely to feed into high school (and thus university) compared to Academic Secondary Schools and which often include families who cannot afford to pay for additional education including many migrant and refugee families.</li> <li>Recruited teachers via face-to-face information events; existing online channels (newsletter, website, Facebook channel and teacher mailing list); direct contact with school deans and via the Vienna Municipal Education Authority who promoted the project.</li> </ul>
<p>NOESIS</p> <p>Greece</p>	<p>i) Students from lower income families.</p> <p>ii) Students with a different mother tongue and cultural inclusion difficulties.</p>	<ul style="list-style-type: none"> <li>Used national data to identify schools with higher levels of students from lower income families and/or Greek as a second language.</li> <li>Used NOESIS' school network to invite teachers to join the project.</li> <li>Offered small-scale training events at NOESIS.</li> </ul>



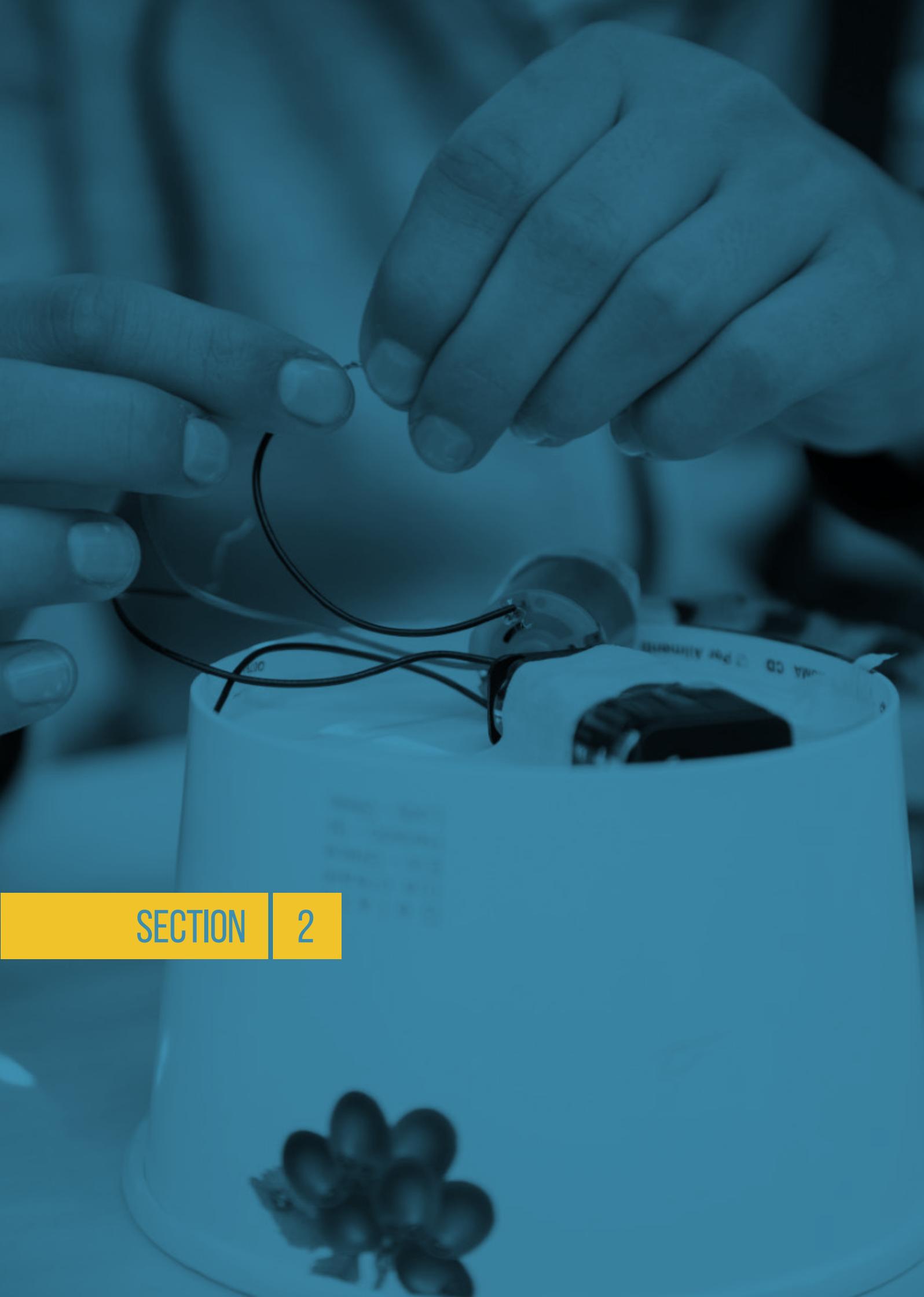
## 1.2 SMALL-SCALE TRAININGS, WORKSHOPS AND TEACHER OBSERVATIONS

Importantly, in the early phase of the project, two teachers were recruited by each partner to act as teacher ambassadors. These ambassadors were critical to the early planning and development work. The ambassadors helped to select and refine the Tinkering activities that would be rolled-out to the other participating schools. They also attended one of the main training events in Milan delivered by The Tinkering Studio of the Exploratorium from San Francisco together with MUST and the University of Cambridge. This training brought together teachers and museum educators to experience Tinkering pedagogy first-hand. It facilitated practitioner discussions around inclusive practice and how best to develop Tinkering activities for the participating schools. The training also enabled discussions that informed the development of the data collection tools used later in the project. These tools were used to support teacher reflections from the wider teacher participant group in relation to the utility of Tinkering for supporting students facing disadvantage. After the training, those Tinkering activities selected for their potential to support students facing disadvantage were tested by each partner with the students of the teacher ambassadors. Feedback from this testing was shared among partners to help fine-tune the activities and arrive at the final Tinkering workshop activity design which the partners used with the other participating schools.

Following the detailed planning work with the teacher ambassadors, the partners engaged with the wider group of teachers recruited to the project as described above. These teachers attended small-scale training events developed and run by the partner institutions. Such trainings were followed by the teachers bringing their students to the museum to take part in a Tinkering workshop. The aims of the small-scale training events were to:

- Familiarise the teachers with the Tinkering approach.
- Introduce the teachers to the Learning Dimensions of Tinkering framework (appendix 2), as well as to practitioner-focussed research relating to science capital, as these two were the founding pillars of the work.
- Introduce and explain the observation and reflection tools that the teachers would be using during and immediately after their visit to the partner institution (see next section). Tools were designed to encourage the teachers to closely observe what happens when their students take part in Tinkering in order to help them identify how the activity could support their students across wide-ranging learning and skill areas, as well as think about the implications of what they observed and learned for their own practice.

At the start of the project each partner planned for 30 teachers to visit their institution with their students. While these numbers were reached for the small-scale training events, the number of workshops for students were lower than planned for some of the partners. This was due to the unpredicted events of the Covid-19 pandemic which saw the partner institutions closing their doors to visitors beginning March 2020 (see Section 3).



SECTION

2

# 2

## DATA COLLECTION AND ANALYSIS METHODS

### 2.1 TOOLS FOR COLLECTING TEACHER IDEAS, PERCEPTIONS AND REFLECTIONS

The partners collected data from the teachers through:

- A structured **Observation Tool** (appendix 3) that teachers completed while watching their students take part in Tinkering activities at the partner institutions.
- An online **Reflection Tool** (appendix 4) that captured teachers' thoughts after they had observed their students doing Tinkering.

Both tools were translated by the partner institutions into native languages and were completed by teachers in their native language.

The Observation and Reflection Tools were built into the training offer provided by the partner institutions for participating teachers. The training introduced the concept of science capital as well as Tinkering as an approach for teaching and learning in STEM.

### 2.1.1 OBSERVATION TOOL DESIGN

The Observation Tool was designed in collaboration with the teacher ambassadors who tested it and offered suggestions for refinement. The partners also contributed to the design of the observation activities. When designing the tool, several factors were considered:

- The need to provide a range of methods for observation enabling teachers to capture and record data in different ways according to their preferences, prior knowledge and skill levels.
- Options for teachers to explore different elements of Tinkering pedagogy (its environment, its facilitation and the learning and skill areas that it can develop) in relation to their individual students.
- The need to provide observation prompts to help the teachers delve deeper into what was happening in relation to student learning, the facilitation by the museum educators and the interplay between the two.
- How to provide rich content that could help frame their thinking while keeping the tool 'light-touch' enough that it did not feel too cumbersome or complex to complete while watching students.



### 2.1.2 REFLECTION TOOL DESIGN

The final tool shown in appendix 4 comprised four observation activities alongside separate pages for making field notes. For the field notes, teachers were invited to record interesting or surprising learning episodes. The four observation activities (A-D) each focussed on a different element of Tinkering pedagogy:

- A/ The elements that create a successful Tinkering environment for learning (resources, materials, room layout, movement around the room etc),
- B / Tinkering facilitation techniques that can engage all learners - especially those less confident with science.
- C / The broad-ranging ways that students can learn when they do Tinkering.
- D / The ways that Tinkering can support students to develop skills in the area of resilience, problem-solving, creative thinking and ingenuity because of the way it can support learners to deal with frustrations, mistakes and being stuck.

The participating teachers were asked to complete observation A during the Tinkering session as they watched their students doing Tinkering. Observations B-D could be completed either during the session or immediately afterwards using their field notes. When using the Observation Tool, the teachers were required to take a step back from their normal 'teaching' role and to observe their students rather than take part in any teaching- something that teachers often have little opportunity to do in school.

The Reflection Tool was designed using an online programme and was sent out to the teachers seven days after their visit to the partner institution. The teachers were also sent a copy of the notes they had made in the Observation Tool (partners made digital copies) to remind them of what they had observed while the experience was still fresh in their mind. The Reflection Tool comprised a mix of closed, scaled and open questions designed to:

- 1 / Elicit critical reflection on what the teachers had observed.
- 2 / Help them to integrate new ideas (derived from observations of Tinkering pedagogy), with their existing knowledge and ideas about teaching and learning.
- 3 / Reflect on what this meant for their own practice, particularly in relation to supporting disadvantaged students and creating more equitable and inclusive teaching and learning opportunities for them in STEM (online reflection tool).



## 2.2 DATA ANALYSIS METHODS

The two data collection tools were designed to work in a sequential way. The thoughts and observations the teachers had while watching their students doing Tinkering were captured in the Observation Tool. These observation notes became the stimulus material for the teachers to complete the online Reflection Tool. The notes made in the Observation Tool were not subjected to individual analysis; however, they comprised the source material for the teachers to complete the Reflection Tool, for which the responses were translated and analysed.

The teacher responses in the online Reflection tool were translated into English for analysis using an online translation programme. These translations were checked by the partners for any translation errors before analysis was undertaken.

The questions in the online Reflection Tool were designed to provide insights into how beneficial the teachers thought that the experience was for their students. Closed and scaled questions provided broad-brush insights into whether they intended to implement the pedagogy in their classroom or share their learning with colleagues. Open questions were included which prompted deeper reflection on how the teachers thought Tinkering could support students facing disadvantage, as well as promoting the teachers to consider how the experience might influence their future teaching practice.

These responses were divided into two key data sets (figure 1) which provided a rich source of qualitative data into which a 'deeper dive' analysis was conducted.

### Deep-dive data set 1: responses to the question...

Do you think that Tinkering was effective for engaging students facing disadvantage such as disability, language barriers or socio-economic disadvantage? Please explain your answer. If you have one, please give an example of how Tinkering supported or engaged a student or students in your class who are facing disadvantage.

### Deep dive data set 2: responses to the questions...

Will you do Tinkering back at school? Y/N/M. Please explain your answer. For example, what Tinkering activity might you do? Or if you do not plan to do Tinkering, please explain why.

Look at your observation notes. Think about the elements of the Tinkering Pedagogy - the environment, activity or facilitation - that you thought were effective. Perhaps you watched a facilitator using questions to help a learner think through a problem rather than give them a solution. Perhaps you saw students setting their own goals and being given time to follow their interest. Describe one feature of Tinkering pedagogy that you would like to try out in your classroom in the box below.

Create a short action plan for implementing this feature of Tinkering pedagogy in your classroom - write down the things you will do to make it happen.

FIGURE 1  
TWO SETS OF QUALITATIVE DATA FROM RESPONSES TO FOUR OPEN QUESTIONS IN THE ONLINE REFLECTION TOOL.



The teacher responses in the two data sets were coded using an open coding approach which identified emerging patterns and themes. Codes were generated inductively from the data:

1. All responses relating to science capital and disadvantage were coded together.
2. Data referring to how the experience influenced or connected with their teaching methods and their intentions for using or applying the pedagogy were coded separately.

The coding schemes for each data set are summarised in figure 2. For data set 1 (responses relating to science capital and disadvantage), 13 codes were aggregated into three main themes. For data set 2 (responses relating to influence on teacher practice), 15 codes were aggregated into five main themes. The coding schemes are described in more detail in appendix 1 which provides code descriptors and example teacher responses for each code. These coding schemes provide a way of articulating the underlying ideas represented within the teachers' responses.

**FIGURE 2**  
CODING SCHEME FOR DATA SET 1 (ABOVE) AND DATA SET 2 (RIGHT)

<p><b>1. Challenge for SEND</b></p> <p><b>2. Inclusive Pedagogical Approach (IPA)</b>          IPA Broadening what counts/valuing different skills          IPA Engaging the usually less engaged          IPA Equity          IPA Learner-centred          IPA Learning from failure, ok to fail          IPA Peer teaching, learning from others          IPA Support for specific SEND</p> <p><b>3. Skill development (SD)</b>          SD Confidence, self-esteem, motivation          SD Creativity          SD Resilience, determination          SD Supporting language development          SD Teamwork, collaboration</p>	<p><b>1. Adopting Tinkering Pedagogy (ATP)</b>          ATP Planning, Orientating, Preparing          ATP Initial adoption ATP Integrating, Synthesizing, Experimenting          ATP Deep adoption</p> <p><b>2. Barriers</b>          Curricular-no time, curriculum too full General difficulty no specific reason given          Physical - space, tools, resources, materials</p> <p><b>3. Confirming existing ideas around learner-centred practice</b></p> <p><b>4. Teacher as change agent</b></p> <p><b>5. Utilizing pedagogical elements of Tinkering (UPE)</b>          UPE Environment, Materials, Resources          UPE Facilitation, Greater Learner Autonomy          UPE Group work, Teamwork, Collaboration          UPE Inclusion, valuing, welcoming          UPE Problem Solving, Challenge, Role of the Goal</p>
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SECTION

3

# 3

## KEY FINDINGS - INSIGHTS FROM THE DATA ANALYSIS

### 3.1 NUMBERS OF TEACHERS RESPONDING

The lock-down imposed across Europe because of Covid-19 meant that the planned events for the students at the participating schools were suspended from March 2020 onwards with consequences for both the quantitative impact of the project and the specific data collection from teachers.

The final numbers of teachers and students who attended the partner institutions for the workshop events up to March 2020 are shown in table 2.<sup>4</sup>

The Online Reflection Tool was designed to be completed after the visit to the partner institution. It was sent out to teachers one week after their visit, with a request to complete it. In total, 120 teachers provided reflections about their experience of observing their students taking part in Tinkering activities.

No question was marked as compulsory and teachers were free to leave sections blank if they chose to, given that this was a voluntary exercise completed in their own time. Some of the questions had been piloted already with the ambassador teachers; their answers to these questions are included in the data set.

TABLE 2  
NUMBERS OF TEACHERS AND STUDENTS PARTICIPATING IN THE ON-SITE WORKSHOP EVENTS

PARTNER INSTITUTION	NUMBER OF WORKSHOPS HELD	NUMBER OF TEACHERS ATTENDING	NUMBER OF STUDENTS REACHED
MUST	30	27	637
NEMO	21	21	465
NOESIS	30	30	692
SGD	13	13	294
COSMOCAIXA	28	28	680
SCN	19	19	342
<b>TOTAL</b>	<b>141</b>	<b>138</b>	<b>3110</b>

<sup>4</sup> This document was prepared in the period April-May 2020 while the partner institutions were still under lock-down waiting to see whether there could be a way to make up the missing numbers by the end of the project in August 2020.



### 3.2

#### INSIGHTS ON IMPACT: TINKERING IN RELATION TO LOW SCIENCE CAPITAL AND SUPPORTING DISADVANTAGE

Of the teachers who answered the question 'Do you think that Tinkering was effective for engaging students facing disadvantage such as disability, language barriers or socio-economic disadvantage?' (n=105), 86% thought that this approach was useful for supporting students facing disadvantage.

Only 4 teachers answered that they did not think this was an effective approach for supporting disadvantage. Interestingly, of the 15 teachers who responded 'maybe', seven gave qualifying responses that suggested that they did think it was useful for supporting disadvantage:

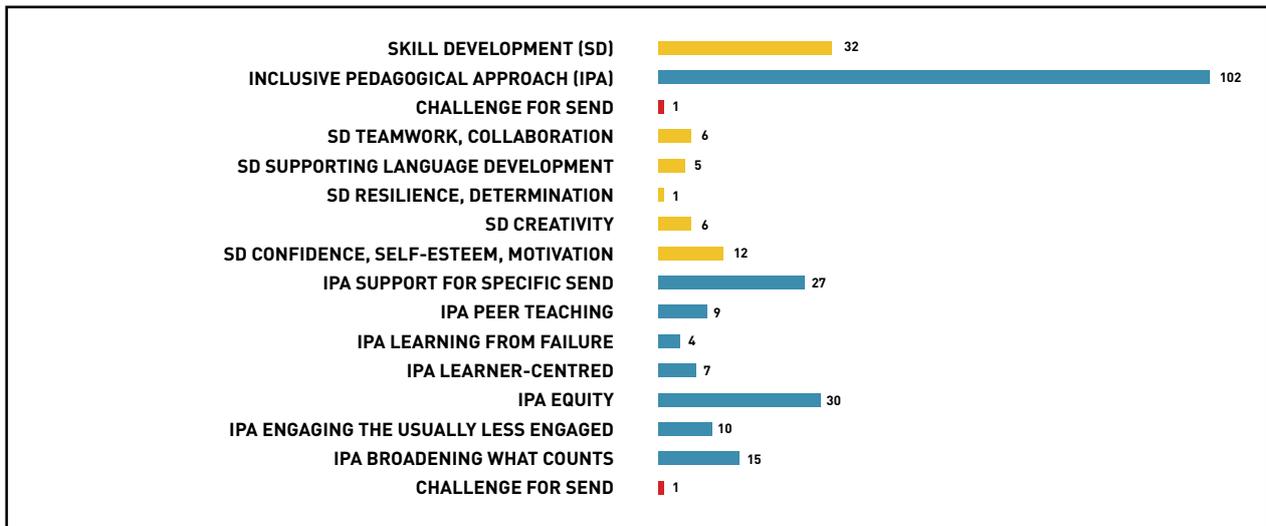
1. *'Encouragement made the indifferent student get actually engaged.'*
2. *'In general, I can say that children who did not respond to the traditional demands of the school in an optimal way, had roles and showed their creativity in the face of tinkering proposals.'*
3. *'If you have time to start a conversation with this student, it can be effective. / Also, language is not always required to achieve results. Undiscovered talents can become visible.'*
4. *'Being a trial and error activity many students who have difficulties can more easily find the solution since they are given the tools to put it to the test.'*

5. *'A student with no interest in whatever happens in the classroom, took over a small role in the group, he was smiling (!) and looked carefully at his classmates.'*

6. *'Among the students, there were some with social problems who I think gave a significantly different participatory picture to the group. They expressed excitement and joy, as in the game, which is not the case in everyday school practice. I believe that the very task that had to be resolved, the one goal in particular, and the ability to try again in case of failure, helped to have all the children involved.'*

7. *'Students with SEN were fully engaged and confident and able to contribute. / Student who finds social interaction difficult did not do the task but he did remain beside his team rather than walking away. All other students were fully engaged and clearly enjoying the task.'*

**FIGURE 3**  
**CODED RESPONSES RELATING TO HOW TINKERING CAN SUPPORT STUDENTS FACING DISADVANTAGE**  
 (SD: SKILLS DEVELOPMENT; IPA: INCLUSIVE PEDAGOGICAL APPROACH)



In total there were 135 coded responses in data set 1 which related to whether and how Tinkering could support students facing disadvantage (figure 3).

These teacher comments demonstrated awareness of specific needs and potential barriers faced by their individual students and cited clear examples of how the teachers thought.

Tinkering could help support these students. Exactly 32 of the 135 responses discussed specific skills that Tinkering could develop for students facing disadvantage. The majority (n=102) referred to Tinkering as being an inclusive approach for teaching and learning in STEM. Approximately one third of these comments (n=27) referenced a specific educational need or disability, suggesting that Tinkering could be **an effective approach for supporting students with SEND** (special educational need or disability):

*'In the class there are two (disadvantaged) pupils and one with self-control problems who decided to form a working group together, of course it would have been better if they mixed with the other classmates, but this still allowed them to work with great harmony between them, without fear of expressing their ideas and achieving results that are up to that of the other groups.'*

*'It gave my two students (one with a physical disability and one with a different mother tongue) the opportunity to try in their own way and in the time they needed to do it. They did so with a little help, and their self-esteem rose sharply.'*

*'I saw students who have been described as "naturally weak" (dyslexic) in the class, work happily in their group by suggesting materials or giving ideas about the connection path or decorating the structure. / This fact boosted their confidence.'*

*'All students had some kind of difficulty (e.g. Learning Disabilities, Dyslexia, Autistic Spectrum Disorders) and from a variety of socio-economic backgrounds. In our activity, this was not a hindrance to their involvement and their joy. / An interesting activity, freedom of action, shared purpose, discretion, and prior 'worked / tested' relationships between students (and teachers) were the 'keys' to success.'*

Of all the qualitative responses that discussed Tinkering and SEND, only one teacher comment mentioned Tinkering as being a potential issue. This related to an individual with autism:

*'Dennis (autism) had great difficulties in working in a group because he had a clear idea of the appearance and function of the marble machine in his head. He could, on the one hand, not understand his colleagues' trial attempts, and on the other hand, for his part, he could not translate the theoretical connections into practical action.'*



This comment indicates that this student was clear about what approach they wanted to take but was finding the social and emotional engagement involved in working with others in a team situation challenging. This contrasted with other teacher responses where Tinkering was cited as being beneficial for students with autism:

*'A student of autism on the occasion of the Tinkering "lab" showed interest and worked with his classmate carefully, methodically, calmly and effectively.'*

*'A boy with slight autistic features felt very comfortable here and was able to demonstrate his creativity.'*

*'I have a student with Autism. He benefited from working with others who helped guide him.'*

It is important to note that while Tinkering can often involve teamwork and working with others, it does not have to. One of the most powerful elements of the Tinkering approach is that it allows a learner to pursue their own personal learning journey and can enable the learner to become fully immersed in their own project as they puzzle out what they want to achieve through iterative design and problem-solving. A possible emerging finding from our data here is that the facilitation approach taken for students with autism needs to be carefully considered in advance of a Tinkering activity and should take into account the individual needs of the student: while some may benefit from working in a collaborative 'team' situation, others may need to be given more individual space and time to work on their own without the additional challenge of having to negotiate with others about what approach to take.

A further one third of the comments coded to 'IPA: Equity' (n=30) discussed the way in which Tinkering served to 'level the playing field' and break down barriers for participation. The emphasis was on the reduced language demand as well as the fact that students could participate on an equal footing irrespective of things like prior STEM knowledge or skills:

*'Language is not always required to achieve results.'*

*'All students could participate equally. It was a practical experience where reading or written comprehension were not essential skills.'*

*'Disadvantaged children do not [negatively] stand out in this open learning space. Everyone has the feeling that they have achieved something.'*

*'A student who does not speak Greek fluently, worked with members of his team actively and effectively to construct what they were asked to. Although he was hesitant at first, he realized that using the same language was not the most basic component of the Tinkering methodology and "joined the group".'*

*'The language used by the facilitators was perfectly understandable and not scientific.'*

*'Some of my students are still learning German. They were able to demonstrate ideas by working the materials, which they might not have been able to formulate.'*

*'The hands-on aspect prevents language as a barrier a student can demonstrate thought and solutions as they are problem solving.'*



*'Some of the pupils have little or no English and really got involved in the workshop. It was great to see those pupils finding a voice in their actions.'*

*'It was a level playing field for students. Those who may be less able academically really shone because failure was seen as a good thing and something to learn from.'*

*'The activities did not require any prior knowledge. Pupils can quickly get to work and inquire and help each other if something initially fails.'*

Other comments (n=15) related to the fact that Tinkering **draws on, encourages and celebrates wide-ranging skills and talents**, and as such could serve to 'broaden what counts' as STEM learning in-line with a Science Capital Teaching Approach (Godec et al., 2017):

*'It is an activity that gives space to different skills compared to those generally required at school.'*

*'Students lacking in terms of learning, have shown with Tinkering that they have practical skills in solving problems like other classmates and have been praised for the results they have achieved with their artifacts.'*

*'I think that in a Tinkering activity everyone can make their own resources available as it allows different approaches: technical, scientific, creative, aesthetic, and it is also fun.'*

*'Hidden talents of students were used for this activity.'*  
*'Creativity is universal.'*

*'Undiscovered talents can become visible.'*

*'This mainly concerns self-confidence and being able to excel in the school environment that is otherwise dominated by cognitive skills.'*

*'The laboratory allowed the use of other skills, besides academic knowledge.'*

*'It allowed a sense of freedom and removed the idea of 'wrong answers'.'*

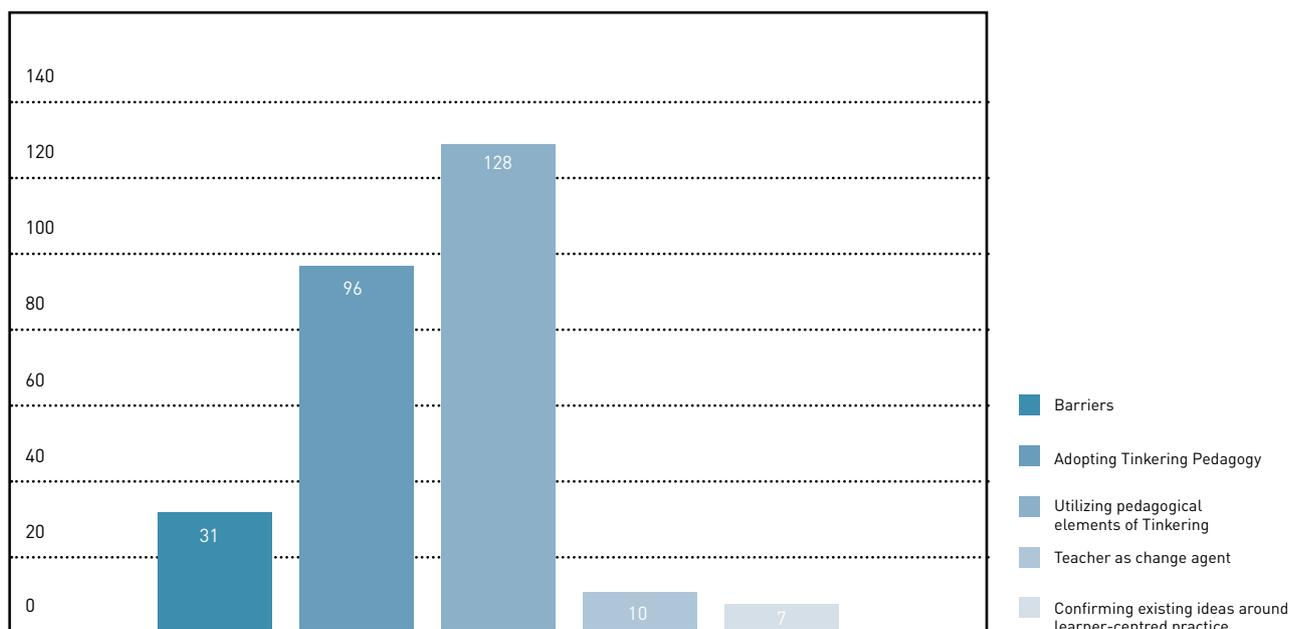


### 3.3 INSIGHTS ON IMPACT: INFLUENCE OF TINKERING EXPERIENCES ON TEACHER PRACTICE

272 teacher comments related to how taking part in this process might shape, influence or impact the participants' teaching practice (figure 4).

These comments related either to the **direct adoption of Tinkering in their own classrooms** or to the **how experience might influence their practice beyond the adoption of Tinkering activities**. These two areas are discussed separately in the following two sections.

FIGURE 4  
CODED TEACHER RESPONSES ABOUT HOW THEY THOUGHT THE EXPERIENCE RELATED TO THEIR OWN PRACTICE





### 3.3.1 DIRECT ADOPTION OF TINKERING IN THE TEACHERS' CLASSROOMS

Exactly 114 teachers responded to the question: 'Will you do Tinkering back at school?' Of these 67% answered that they would implement it, 27% answered maybe and only 6% (n=8) answered definitively that they would not. Responses of seven of the eight teachers who said they would not do Tinkering are shown below (one teacher did not provide a qualifying reason).

The reasons given mainly related to lack of space, resources or equipment:

1. *'The request and management of the material is really huge. Not to mention that our school is really very close to the museum.'*

2. *'The classrooms of our school hardly fit the students seated. / - Cost of purchase of materials is not covered. / - The curriculum is already excessive to allow time for such activities. / - The teaching time is 45 minutes with incapable completion time. There is no provision for more minutes. Even if there was a second hour, the break would disrupt the concentration of students. / - Disruption / noise in the room would cause problems for colleagues.'*

3. *'Some students are not interested in the subject and may potentially harm themselves with scissors. For example, one student burst into laughter, fell down and luckily he was not hurt.'*

4. *'We do not have the spaces in which to carry out these activities: the school has grown in recent years as a number of students and many laboratories have been dismantled to be transformed into classrooms. In the classrooms of my classes there is no physical space to carry out unstructured activities because they are very numerous.'*

5. *'Because there is no proper equipment.'*

6. *'We do not have the spaces in which to carry out these activities: the school has grown in recent years as a number of students and many laboratories have been dismantled to be transformed into classrooms. In the classrooms of my classes there is no physical space to carry out unstructured activities because they are very numerous.'*

7. *'We already do lots of student led activities and experiments. / With Tinkering we did a marble run, the level of resources required for an activity like that is not realistic within a school. / Possibly a different activity would be transferable but we only have done the marble run. / If the class was run with resources the teacher has or could take home that would be much more effective (in my opinion). / For example, doing Distance, speed & time activities using remote controlled cars. Would be very fun & engaging but also a low expense, easily organized and small storage thing for the teacher. And it would not be particularly expensive for the program to then donate the cars to the school.'*

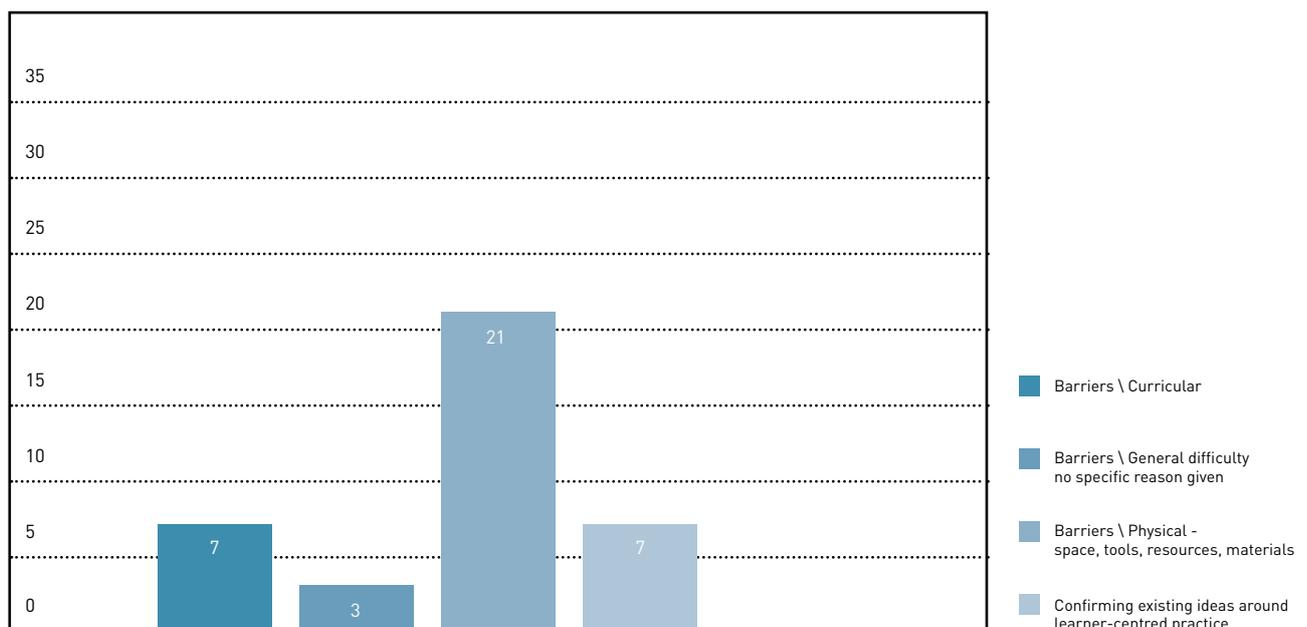


For some teachers (n=31 comments) they could see the benefits of Tinkering for their students but expressed concerns about their capacity to replicate Tinkering in school due to lack of space, resources, time or institutional buy-in. Of these barriers for adoption (figure 5), most of the comments (n=21) related to physical barriers such as lack of resources, equipment or space.

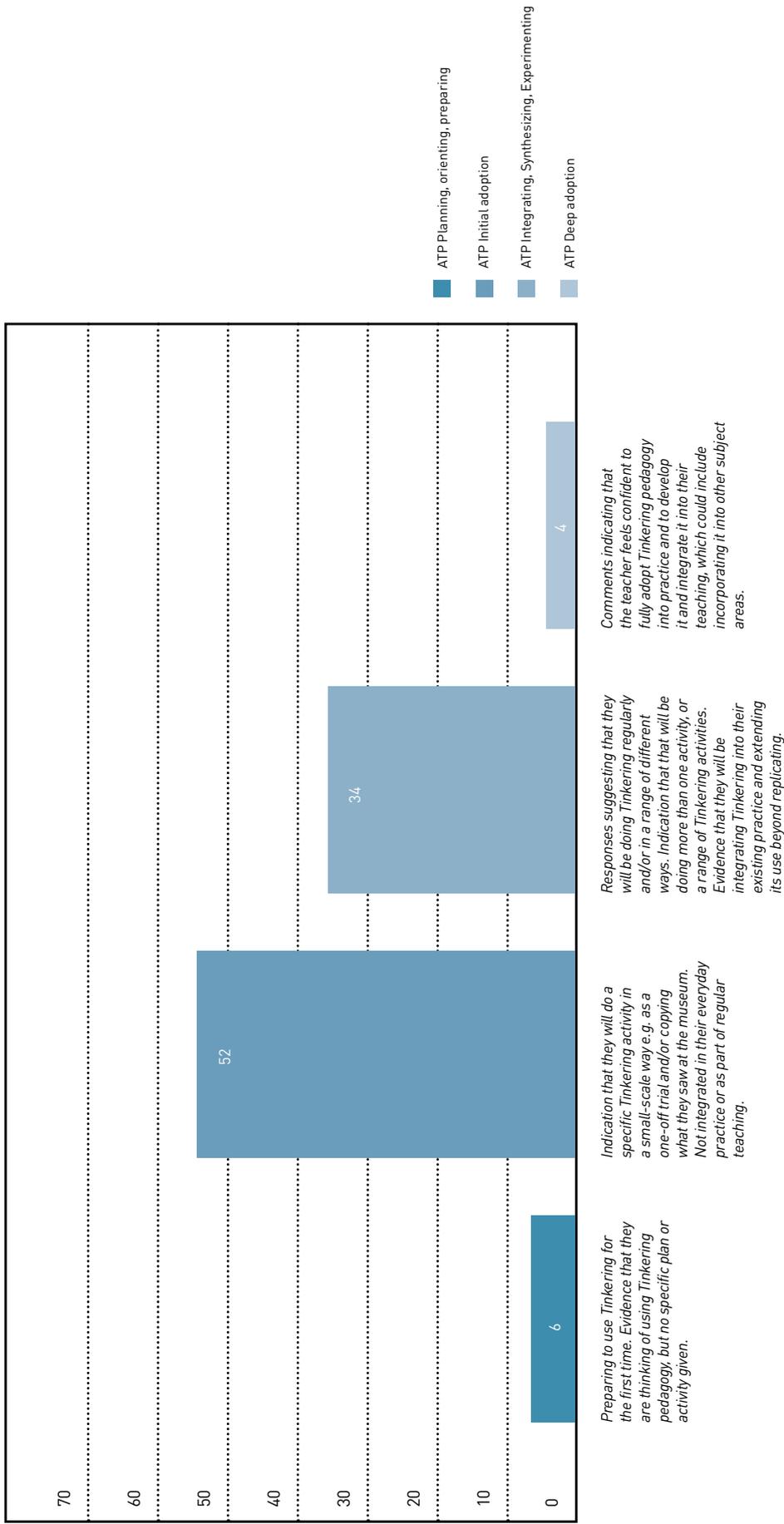
The second largest group of teacher comments about how Tinkering related to their practice (n=96) referred to running specific Tinkering activities back at school.

These were coded as 'Adopting Tinkering Pedagogy (ATP)' and seemed to fall on a spectrum of increasing depth and reach in relation to the planned implementation (figure 6).

**FIGURE 5**  
CODED RESPONSES RELATING TO BARRIERS FOR UPTAKE



**FIGURE 6**  
RESPONSES REFERRING TO DOING TINKERING ACTIVITIES REPRESENTING A SPECTRUM OF DEPTH OF INTEGRATION INTO PRACTICE



WIDER ADOPTION, DEEPER INTEGRATION WITH PRACTICE



Most of the comments coded to ATP (n=52) referred to trying out or replicating the Tinkering activity they had observed, or doing another similar Tinkering activity as a trial or one-off in the first instance:

*'I want to start using the marble machine in the classroom. The assignment we did in the workshop for teachers (scribbling machines) also fits in with our lessons.'*

*'First of all I would like to try a similar assignment with my group, such as creating a marble machine.'*

*'The activity with simple electrical circuits.'*

*'The activity with the lights lit behind the paper cards.'*

*'I would like to tinker a chain reaction with them in the summer or a scribbling machine.'*

*'Ball track or chain reaction machine.'*

*'Card Box or Light Box / perhaps Squishy Circuits.'*

The next largest group of responses (n=34) were from teachers who indicated they would be implementing more substantial, longer-term programmes, such as running a series of different Tinkering activities over several weeks or teaching whole sections of the curriculum using a Tinkering approach:

*'We already organized a Tinkering week in November and will organize another in March. The proposed activities were the creation of means of transport with egg cartons.'*

*'Already in the current school year, after having structured and set up the school laboratory, I started a project that proposes tinkering activities: once a month pupil experience a different proposal.'*

*'We have organized our education in such a way that we work on a theme from school to vacation school-wide. / Upcoming theme is about "Lights" here it is nice to create a circuit, hack the Christmas lights or discover how the children can work with lights. / I am thinking, for example, of the paper circuits.'*

*'I will definitely use Tinkering in the teaching of Electricity, such as electrical circuits, conductors, etc. in the 5th class in primary school. I think it is a unit, perhaps the most appropriate subject, for students to get to know the new approach. The existence of many materials-objects positively influences the application of Tinkering.'*

*'In my classes, I used simple circuits as a tool both to engage students in a learning process and to work on their relationships. After the Tinkering activity at NO-ESIS, this practice will be enriched – students already ask for it!'*

*'Our school has a robotics lab and LEGO MINDSTORMS EV3. So there is the possibility of running Tinkering activities with simple constructions that use motors and sensors to create music, alarms, paintings, color recognition, etc.'*

*'I already do (assign to students) the application with light circuits and batteries (because of my specialty: Science teacher). I would definitely ask them to make Christmas cards with lights flashing when we open the card, but also to build robots with motors or lighthouses with a rotating light.'*



At the far end of the spectrum were a small number of comments (n=6) suggesting a strong intention to do Tinkering but also indicating that the teacher was still in a planning or orientation phase, thinking through ideas and possibilities as opposed to having a firm idea or plan:

*'I don't have any activity in mind yet, but I'm definitely looking for fun ideas.'*

*'I got to know several ideas thanks to this EU project. As several teachers have been involved in aiding in this EU project I am convinced that they are open for collaboration in future, e.g. on offering the "marble machine" also to other classes. I also liked the "light show" and playing with simple electronics creatively - my favourite experience in Milano.'*

*'I really liked the activity of the toy; it can be made with old toys, or applied to animal studies (it had been done years ago): a fish, etc. Or simply apply that way of guiding the task in different situations of manipulative activities.'*

At the other end (n=4) were comments which indicated the teacher would be adopting Tinkering pedagogy extensively into practice and integrating it widely, across year groups and subject areas.

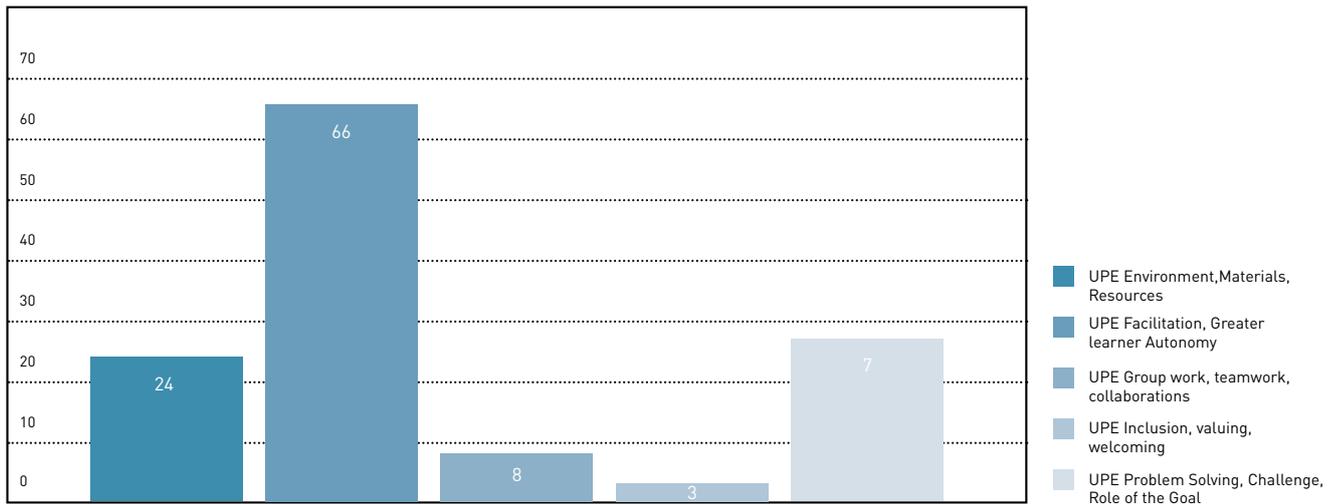
*'I think I will incorporate Tinkering into the SESE (Social Environmental and Scientific Education) curriculum, particularly in Science. I think it would translate well into outdoor activities i.e. gardening, development of outdoor resources and engagement in outdoor team activities.'*

*'We will do tinkering at school because we are in the "magnet" program and we are creating a space similar to that of cosmocaixa in our school.'*

*'In my school a specific Tinkering space is being created. We also carry out STEM methodology workshops weekly.'*

*'I actually want to convert all the technology lessons to tinkering activities. / The first will be something with light. Because that fits our theme.'*

**FIGURE 7**  
**CODED RESPONSES RELATED TO HOW TEACHERS MIGHT ADOPT ELEMENTS OF TINKERING PEDAGOGY INTO THEIR PRACTICE**



### 3.3.2 **INFLUENCE ON TEACHERS' PRACTICE BEYOND ADOPTION OF TINKERING**

Of the 272 teacher comments that discussed influence on practice, 128 of these referred to how teachers might utilise elements of Tinkering pedagogy. These were coded to 'UPE: Utilising Pedagogical Elements of Tinkering' (figure 7)

Of these 128 comments, the majority (n=66) were about Tinkering facilitation methods, and referenced specific techniques observed which mainly related to: i) using questioning techniques that enable greater thinking time and a chance for students to puzzle things out or work through getting stuck, and ii) adopting a more learner-centred approach in which, for example, learners are given time to try for themselves, set their own goals, problem solve in an iterative way, and come up with creative solutions. Example of comments coded to 'UPE Facilitation' (n=66) are shown below:

UPE Facilitation: responses relating to questioning techniques:

*'Let them try and simply accompany with questions.'*

*'Train the ability to give fewer answers and provoke more questions, exactly. Coming up with interesting questions requires reflection and especially filming.'*

*'What seems most interesting, and most difficult, is asking good questions to guide the process. Sometimes it is easy, but sometimes it is not at all. / I think it is also important to make the reflections at the end. Participation is much higher and richer.'*

*'Ask more questions instead of giving an answer.'*

*'When it comes to instructions, it will be important not necessarily to give tips, but to guide the children with questions in their own approaches and to remind them in phases of frustration of the things that they have already achieved and to remind them that they are not alone to help them regain motivation.'*

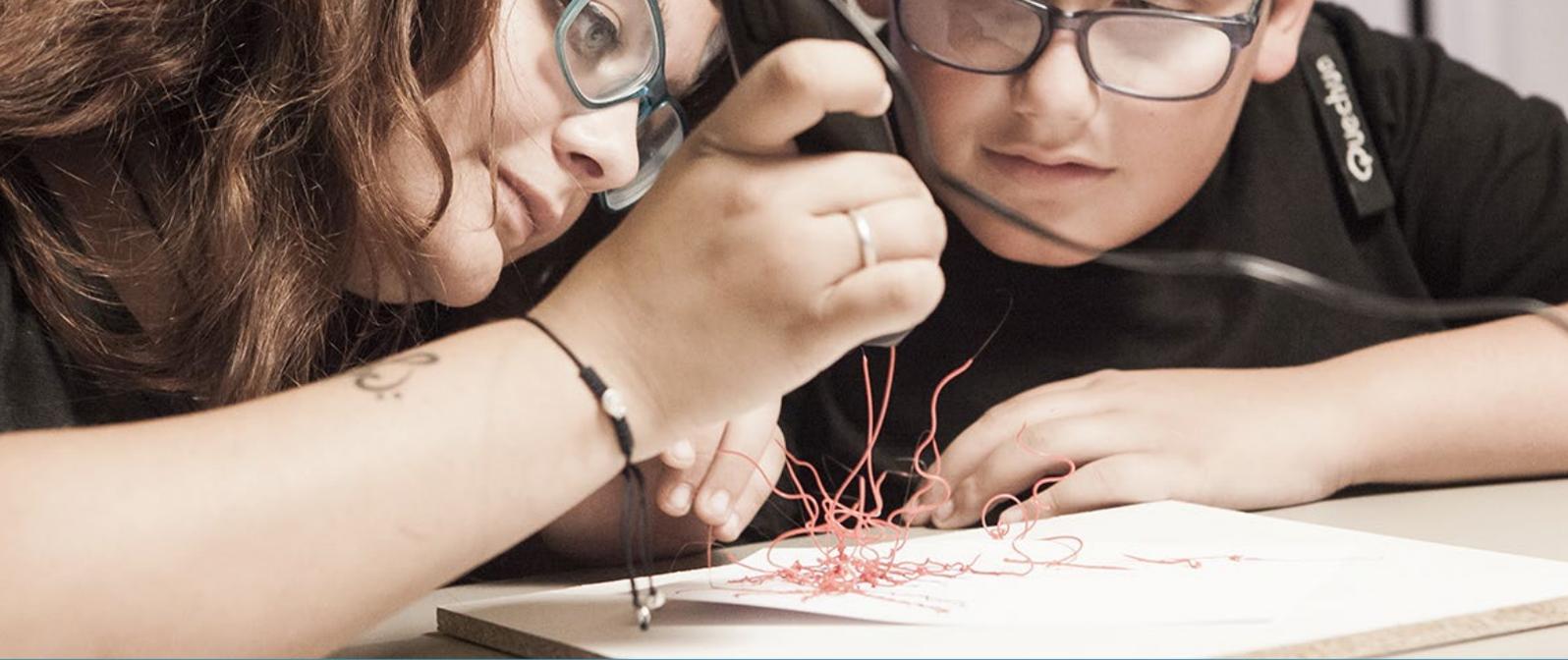
*'Do not rush to answer unanswered questions yourself but try to trigger the thoughts for a possible solution with your own questions. / Allow and discuss deviating answers and integrate them as a possible solution.'*

*'Asking questions instead of giving answers is a good concept that I already applied to my Tinkering group.'*

*'The teacher should get out of the usual pattern of providing answers to students by asking questions that help them find answers to the questions themselves.'*

*'Pay attention to myself and my trainee that we do not immediately give an answer but that we ask a question back.'*

*'Be mindful of my own questioning and avoid giving straight answers.'*



UPE Facilitation: responses relating to adopting a learner-centred approach and encouraging and enabling greater learning autonomy:

*'I would now leave more to the children when it comes to problem solving. In addition, I would now take more time for reflection by the students. Because of the time, I often give short feedback at the end about the great solutions that children have come up with, but I could let them explain more about it myself.'*

*'Show enthusiasm for personal ideas and goals to enhance their creativity.'*

*'The use of guided discovery to enable children to interrogate creative solutions to the issues that arose.'*

*'The trump card is the attitude of the facilitator... it stimulates to find solutions by exploiting the abilities that it identifies in the pupils: in my opinion these attitudes are those that I believe are fundamental in the classroom - stimulate curiosity, raise questions and provide the tools to find the answers for yourself.'*

*'Let (the students) try without worrying about intervening to make suggestions.'*

*'From the guidance section, we would particularly like to apply the 'sustaining' part; allow thinking time so that the students can come up with their own ideas and also to suggest suggestions or answers to questions. / In addition, the principle that everything is good, so appreciate the work and process of the students, we find very conducive to the development of the students.'*

*'Surely I would like to have both a pedagogical and scientific competence that can leave children free to experiment and always value what they have produced without losing the guiding thread!'*

*'Facilitating, allowing children to try for themselves.'*

*'I will try to give more time for thought and make suggestions before offering a solution.'*

*'While in the beginning, children who were used to finding a ready-made answer from their teacher found it difficult to take initiatives to solve problems and difficulties, they were slowly released when they received no answer but a question instead. So they were forced to find their own solutions.'*



For some of the teachers, the experience of working with the partner institution served to confirm their existing ideas and teaching and learning methods. Seven teachers indicated that what they had experienced reflected what they were already doing and that this had reinforced their understanding of the inclusiveness of approaching STEM in this way. For example:

*'As a teacher, the workshop reminded me again that students should be given a lot of time to try out new things.'*

*'The flow of activity was as it should be. Facilitators intervened at the right time, with questions, correct observations and not ready solutions. / Exactly this attitude I try to keep in the classroom. With constant questions to help my students get to the solution. I think students today have lost a great deal of curiosity. This may be due to the easiness of access to information.'*

10 teachers indicated a desire to create positive change, relating Tinkering beyond their own classroom and into their wider school community. Their responses were coded to 'teacher as change agent' and included references to:

- Disseminating what they had learned to other colleagues (*'We tackle it throughout the school. / We have planned a theme from holiday to holiday. / We prepare the themes together with all the teachers. / During a meeting this week I involved colleagues in this process. / Together we plan the new theme next week. We then look for materials and activities together. In this way we lower the threshold for starting Tinkering.'*)
- Setting up their own Tinkering labs and clubs across the school for multiple classes (*'We have a spare classroom, our plan is to turn this into a technology classroom. Materials can then be used multiple times just like in Nemo. Each class in school can then use this room.'*)
- Drawing on the skills of other practitioners (including in museums and science centres) to support their wider use of Tinkering back at school (*'Contact the science gallery as they offered to help with resources I could use for tinkering in my classroom'*)

It is important to note that while only a small number of comments were coded to 'teacher as change agent', there was a largely positive response to the closed question: 'Will you speak with colleagues at school to share what you have learned about Tinkering?' 100% of teachers who completed the online Reflection Tool answered this question with 89% stating that they would speak with colleagues, 10% stating maybe and only one teacher stating that they would not.



SECTION

4

# 4

## CONCLUSIONS

In total, 120 teachers from six countries completed the online reflection tool which has provided the consortium with some clear insights into what the teachers and the students experienced when they visited the partner institutions to take part in Tinkering activities. Their responses indicate that:

1 / For most of the participating teachers, this was an extremely positive experience which they saw as highly beneficial for their students developing broad-ranging skills, particularly in the areas of collaboration, teamwork, problem-solving, resilience and creativity.

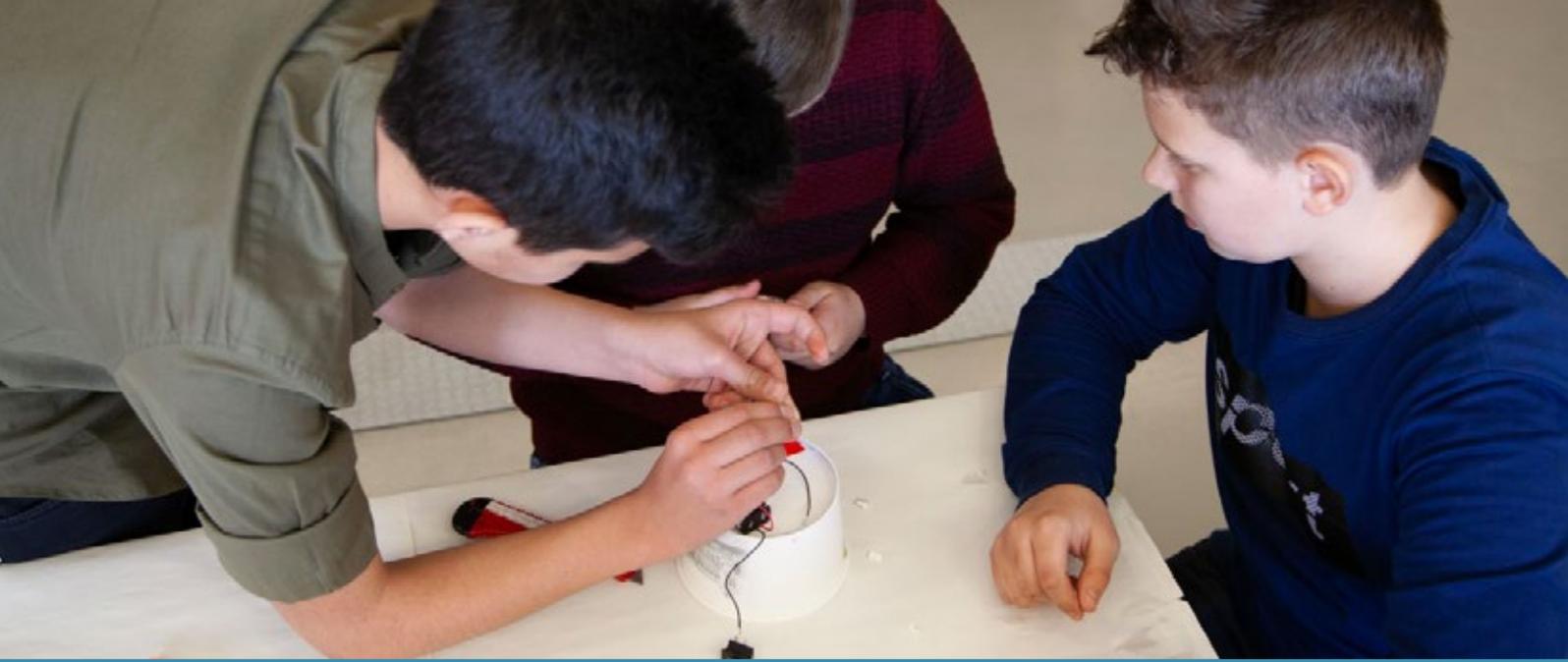
2 / Tinkering was strongly associated with supporting students who are also non-native speakers, largely because it has a low language demand, but also because it can also encourage language development.

3 / Teachers saw evidence of Tinkering serving to 'level the playing field' for students with SEND and those with lower science capital (those who identify less with traditional STEM learning approaches) because of the way Tinkering deeply values their existing skills, interests and talents, encourages creativity, provides multiple pathways for success and therefore boosts their motivation and confidence. Teacher reported that this enabled them to flourish and succeed.

4 / The experience of observing Tinkering-in-action supported teachers' reflections on their own practice and enabled them to see how they could utilise some of the most learner-centred elements of the pedagogy in their own practice.

5 / Most teachers who took part in this project are likely or highly likely to try out Tinkering in their own classroom. For the teachers who were unsure if they would implement Tinkering back at school, most had concerns around physical space and lack of resources.

It is not possible to know whether the project and its outputs will lead directly to wider and deeper adoption of the Tinkering approach at school, but we are confident that we have sown seeds that will lead to increased learner-centred teaching and learning approaches for many of the teachers who took part. Our experience during the three years of this project, corroborated by the teachers' own reflections, highlighted the important role of the partner institutions in maintaining their relationships with these schools, helping them to identify ways to continue to implement Tinkering as part of providing accessible and inclusive learning opportunities on-site. The project has highlighted ways to foster a close collaboration between museums and schools in general, that can encourage more engaging, inclusive and equitable STEM learning experiences for learners facing educational, social, cultural or economic disadvantage.



The main message emerging from the project, and in particular from the work with the teachers, is that

**Tinkering pedagogy can foster a more inclusive approach to STEM learning for all students, and particularly those facing disadvantage in STEM learning with low levels of science capital.**

This is a strong message. It shows not only the potential impact of this innovative pedagogy, but also how its constituent elements – i.e. setting a particular learning environment or facilitation style – can become important tools for looking into, and improving, one’s own practice. The project offered a powerful experience to all participants, we hope now that its legacy can be of help to the wider education community.

<b>CODE BOOK 1: CODING SCHEME FOR DATA SET 1 (ALL RESPONSES RELATING TO SCIENCE CAPITAL AND DISADVANTAGE)</b>	
<p><b>1. CHALLENGE FOR SEND</b></p> <p>Negative comments suggesting this is not an approach that is helpful for supporting students facing disadvantage</p>	<ul style="list-style-type: none"> <li>Dennis (autism) had great difficulties in working in a group because he had a clear idea of the appearance and function of the marble machine in his head. He could, on the one hand, not understand his colleagues' trial attempts, and on the other hand, for his part, he could not translate the theoretical connections into practical action.</li> </ul>
<p><b>2. Inclusive pedagogical approach (IPA)</b></p> <p>Parent node for responses that discuss Tinkering as an inclusive teaching and learning approach for STEM.</p>	
<p><b>IPA Broadening what counts and valuing different skills</b></p> <p>Tinkering as an approach for encouraging, developing and or valuing broad-ranging experiences, skills and behaviours. This is included responses about enabling students to flourish according to their abilities and otherwise 'hidden' talents.</p>	<ul style="list-style-type: none"> <li>I think that in a Tinkering activity everyone can make their own resources available as it allows different approaches: technical, scientific, creative, aesthetic, and it is also fun;</li> <li>It is an activity that gives space to different skills compared to those generally required at school;</li> <li>Undiscovered talents can become visible.</li> </ul>
<p><b>IPA Engaging the usually less engaged</b></p> <p>Tinkering as an engaging approach for students who are usually less interested and/or engaged in the traditional science classroom environment.</p>	<ul style="list-style-type: none"> <li>Students who do not usually participate in the classroom for a variety of reasons, were actively involved because they were members of their group and had to offer. So that helped them become more mobile;</li> <li>Tinkering promotes skills as well as the technology lesson I teach. I have often seen students with distracted attention get absorbed by interesting constructions and yet they come up with original solutions for movement, lighting, etc.</li> </ul>
<p><b>IPA Equity</b></p> <p>Tinkering as a fair/equitable approach because it gives extra opportunity to those who would normally be at a disadvantage and/or it removes or diminishes advantages of the other students. References to levelling the playing field e.g. by reducing the language burden.</p>	<ul style="list-style-type: none"> <li>Even pupils with language barriers were able to work without problems and were fully involved; language was less needed because things could be shown or tried out;</li> <li>There were no differences between the students in the Tinkering activity, everyone could pursue their own creative ideas regardless of their background.</li> </ul>
<p><b>IPA Learner-centred</b></p> <p>Personalised approach. Learner-centred. Working at their own pace, ability level, interest level.</p>	<ul style="list-style-type: none"> <li>Every child thinks of activities at his own level that he can handle. You almost always have success experience. This motivates.</li> <li>The goals that each group had to accomplish were mainly on the cognitive level, giving each student the opportunity to engage with it on the basis of their own interests and preferences.</li> </ul>
<p><b>IPA Learning from failure, ok to fail</b></p> <p>Personalised approach. Learner-centred. Working at their own pace, ability level, interest level.</p>	<ul style="list-style-type: none"> <li>Pupils can quickly get to work and inquire and help each other if something initially fails;</li> <li>Those who may be less able academically really shone because failure was seen as a good thing and something to learn from.</li> </ul>
<p><b>IPA Peer teaching, learning from others</b></p> <p>Specific responses about Tinkering encouraging and enabling students to learn from each other.</p>	<ul style="list-style-type: none"> <li>It was not the teacher who conveyed scientific knowledge but the students themselves through guided discovery and through many tests came up with solutions to the problems that arose. This has helped students with learning disabilities become more involved, express their opinion and test their ideas more courageously;</li> <li>It also allowed for the student to be encouraged and supported by their peers when working in their groups, rather than just adults.</li> </ul>
<p><b>IPA Support for specific SEND</b></p> <p>Tinkering as a means for supporting individuals with SEND and/or examples of SEND</p>	<ul style="list-style-type: none"> <li>A student of autism on the occasion of the "lab" Tinkering showed interest and worked with his classmate carefully, methodically, calmly and effectively.</li> <li>One child in particular, ADHD, who has numerous difficulties in expressing himself at school, was a protagonist of his group with Tinkering.</li> </ul>

### 3. Skill development (SD)

Parent node for responses that discuss Tinkering as an inclusive teaching and learning approach because of the way it can help to support, develop or encourage particular skills for students facing disadvantage.

<b>SD Confidence, self-esteem, motivation</b>	<ul style="list-style-type: none"><li>• The most shy boys, taken by the enthusiasm, managed to come forward by giving their contribution.</li><li>• This mainly concerns self-confidence and being able to excel in the school environment that is otherwise dominated by cognitive skills</li><li>• Engaged students as they collaborated with their classmates on discovery and experiential activities thereby enhancing their self-confidence</li></ul>
<b>SD Creativity</b>	<ul style="list-style-type: none"><li>• They can participate with their creativity.</li><li>• The most difficult pupils in school disciplines have shown to have greater creativity in solving practical problems related to the construction of the ball track</li></ul>
<b>SD Resilience, determination</b>	<ul style="list-style-type: none"><li>• In the different groups there were boys with poor skills due to language difficulties and lack of environmental stimuli. Furthermore, a disabled pupil was present. All the boys, indiscriminately, showed commitment and determination and implemented other skills more related to "know-how"</li></ul>
<b>SD Supporting language development</b>	<ul style="list-style-type: none"><li>• language is encouraged through collaboration and consultation</li><li>• I think it is effective for vocabulary because they see / hear many things and because they have to consult a lot they use language and hear new words.</li><li>• They hear and use a lot of language which makes them grow.</li></ul>
<b>SD Teamwork, collaboration</b>	<ul style="list-style-type: none"><li>• Tinkering encourages working in a group because all children want to be successful.</li><li>• A student who struggles with social contacts worked great in a team.</li><li>• Students were in groups that allowed interaction and communication skills development</li></ul>

**CODE BOOK 2: CODING SCHEME FOR DATA SET 2 (ALL RESPONSE RELATING TO HOW THE EXPERIENCE MIGHT INFLUENCE PRACTICE)**

**1. Adopting Tinkering Pedagogy (ATP)**

Responses that indicated that the teacher intends to do Tinkering activity/activities back at school with their students. Responses sat on a spectrum of readiness and preparedness for adoption - from being in the initial planning stages through to being ready for a broad and widespread adoption across multiple lessons and / or curriculum areas.

**ATP Planning, Orientating, Preparing**

Preparing to use Tinkering for the first time. Evidence that they are thinking of using Tinkering pedagogy, but no specific plan or activity given.

- I don't have any activity in mind yet, but I'm definitely looking for fun ideas.
- I got to know several ideas thanks to this EU project. As several teachers have been involved in aiding in this EU project I am convinced that they are open for collaboration in future, e.g. on offering the "marble machine" also to other classes. I also liked the "light show" and playing with simple electronics creatively - my favourite experience in Milano.

**ATP Initial adoption**

Indication that they will do a specific Tinkering activity in a small-scale way e.g. as a one-off trial and/or copying what they saw at the museum.

- First of all I would like to try a similar assignment with my group, such as creating a marble machine;
- Card Box or Light Box / perhaps Squishy Circuits;
- I would like to tinker a chain reaction with them in the summer or a scribbling machine.

**ATP Integrating, Synthesizing, Experimenting**

Responses suggesting that they will be doing Tinkering regularly and/or in a range of different ways. Indication that that will be doing more than one activity, or a range of Tinkering activities. Evidence that they will be integrating Tinkering into their existing practice and

- Already in the current school year, after having structured and set up the school laboratory, I started a project that proposes tinkering activities: once a month pupils experience a different proposa;
- In the current school year I organized a tinkering laboratory to be implemented once a month, using different activities experienced during the courses at the museum: scrambling machines, cardboard Automata. We will experience others in the months to come.

**ATP Deep adoption**

Comments indicating that the teacher feels confident to fully adopt Tinkering pedagogy into practice and to develop it and integrate it into their teaching, which could include incorporating it into other subject areas.

- I actually want to convert all the technology lessons to tinkering activities. / The first will be something with light. Because that fits our theme.
- We will do tinkering at school because we are in the "magnet" program and we are creating a space similar to that of cosmoaixa in our school.

**2. Barriers**

Parent code for all references relating to issues, challenges and/or potential barriers for working in this way back at school in their own practice.

**Curricular-no time, curriculum too full**

- The curriculum is already excessive to allow time for such activities. / The teaching time is 45 minutes with incapable completion time. There is no provision for more minutes. Even if there was a second hour, the break would disrupt the concentration of students.
- It is also difficult to run such an activity for 25 students with only one teacher in the classroom simply called a lab and the time is only 45 minutes at the most.

**General difficulty no specific reason given**

- I could implement no such an activity in class.
- Unfortunately, it is difficult to set up for a state school

**Physical - space, tools, resources, materials**

- Because there is no proper equipment.
- having a suitable place (at the museum there was a large space arranged, with lots of material, well classified and ordered)
- The main obstacle to carrying out the activity consists in the difficulty of putting together all the materials that can be used for Tinkering activities.

### 3. Confirming existing ideas around learner-centred practice

References which indicate that the teacher is already working in this way and that the training has confirmed for them that this is a valuable approach.

- The flow of activity was as it should be. Facilitators intervened at the right time, with questions, correct observations and not ready solutions. / Exactly this attitude I try to keep in the classroom. With constant questions to help my students get to the solution. I think students today have lost a great deal of curiosity. This may be due to the easiness of access to information;
- Often during lessons at school I use this the system of not giving answers but of posing the problem and letting children find the solution.

### 4. Teacher as a change agent (TA)

Responses that indicate the teacher will be championing Tinkering at their schools, that they will be a leading player for adopting Tinkering more widely or that they will be attempting to influence and bring about change beyond their individual classroom or classes.

- We tackle it throughout the school. / We have planned a theme from holiday to holiday. We prepare the themes together with all the teachers. / During a meeting this week I involved colleagues in this process. / Together we plan the new theme next week. We then look for materials and activities together. In this way we lower the threshold for starting Tinkering;
- Involve colleagues and "spread" this method.

### 5. Utilizing pedagogical elements of Tinkering (UPE)

Parent code for responses relating to what the teachers have learned about Tinkering pedagogy, what they most value and/or what they will take forward in their own practice.

<p><b>UPE Environment, Materials, Resources</b></p>	<ul style="list-style-type: none"> <li>• The environment and the wealth of materials available certainly play a fundamental role.</li> <li>• Arrange the materials so that children can walk different routes and see more from others and learn more from each other.</li> <li>• I also liked the layout of the environment as all resources were based in the centre and each station was well spaced and allowed for movement.</li> <li>• use different tables, different corners of the lab.</li> </ul>
<p><b>UPE Facilitation, Greater Learner, Autonomy</b></p>	<ul style="list-style-type: none"> <li>• Let them try without worrying about intervening to make suggestions</li> <li>• The facilitator focuses on the process. He notes with the children that there is a problem and gives the children the space to think about a solution themselves. I find that valuable.</li> <li>• Facilitating, allowing children to try for themselves</li> <li>• Support in times of "frustration" in the form of suggestions and questions to them as opposed to a more instructional- teacher-centred teaching</li> </ul>
<p><b>UPE Group work, Teamwork, Collaboration</b></p>	<ul style="list-style-type: none"> <li>• I would like to strengthen the spirit of collaboration in teamwork, allow everyone to reinforce their self-esteem and sense of belonging. To stimulate them to help each other (social and emotional involvement)</li> <li>• what I would like to bring to class in Tinkering is above all the idea of working in a group in a freer environment than the class setting, but with specific rules</li> </ul>
<p><b>UPE Inclusion, valuing, welcoming</b></p>	<ul style="list-style-type: none"> <li>• Involve everyone in order to make them feel well welcomed and welcome</li> <li>• I would try to encourage students with less confidence and help with appropriate questions to correct possible construction errors or to provide more scientific explanations about why something is not working. Finally, I would reward any effort because we learn from our mistakes and because effort counts.</li> </ul>
<p><b>UPE Problem Solving, Challenge, Role of the Goal</b></p>	<ul style="list-style-type: none"> <li>• I find it interesting to propose challenges and see how students solve them from different points of view, and the teacher accompanies them.</li> <li>• Use iterative processes to solve problems / - find alternative solutions</li> <li>• The ability offered to students to have the time to discover what they are looking for and to achieve their goal.</li> </ul>

# LEARNING DIMENSIONS

## of Making and Tinkering

Valuable learning experiences can be gained through making and tinkering. Use this framework to notice, support, document, and reflect on how your tinkering environment, activities, and facilitation may have supported or impeded such outcomes.

### Initiative & Intentionality

- Actively participating
- Setting one's own goals
- Taking intellectual & creative risks
- Adjusting goals based on physical feedback and evidence

### Problem Solving & Critical Thinking

- Troubleshooting through iterations
- Dissecting the problem components
- Seeking ideas, tools, and materials to solve the problem
- Developing work-arounds

### Conceptual Understanding

- Making observations and asking questions
- Testing tentative ideas
- Constructing explanations
- Applying solutions to new problems

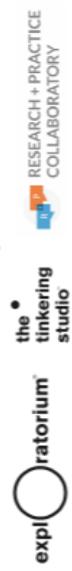
### Creativity & Self-Expression

- Playfully exploring
- Responding aesthetically to materials and phenomena
- Connecting projects to personal interests and experiences
- Using materials in novel ways

### Social & Emotional Engagement

- Working in teams
- Teaching and helping one another
- Expressing pride and ownership
- Documenting / sharing ideas with others

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# OBSERVATION TOOLKIT A GUIDE FOR TEACHERS WATCHING TINKERING

## OBSERVATION TIPS

- 1 / PLEASE DON'T JOIN IN WITH FACILITATION TODAY – USE THIS TIME TO OBSERVE AND THINK ABOUT WHAT YOU SEE AND HEAR.
- 2 / USE THE BLANK PAGES 2-3 FOR YOUR OWN FIELD NOTES.
- 3 / AIM TO DO [A] WHILE YOU WATCH YOUR STUDENTS TINKERING.
- 4 / DO [B] - [D] EITHER WHILE YOU WATCH YOUR STUDENTS OR SOON AFTERWARDS TO HELP CONSOLIDATE YOUR THINKING.

ACTIVITY	WHAT YOU WILL DO	PAGE
FIELD NOTES	Capture conversations and learning episodes that interest or surprise you.	2
[A] ENVIRONMENT	Explore how Tinkering environments support learning and engagement.	4
[B] FACILITATION	Observe Tinkering facilitation techniques that engage all learners - especially those less confident with science.	5
[C] BROADENING WHAT COUNTS AS LEARNING	Look out for different ways students learn when they do Tinkering.	6
[D] STRUGGLE AND SUCCESS	Think about how frustration in Tinkering can build skills like resilience, innovation and problem-solving.	7

\*The **appendix** contains the **Learning Dimension of Tinkering** framework which can support your understanding of the broad dimensions of Learning in Tinkering.



## FIELD NOTES

Consider...

- Are all learners enthusiastic and participating?
- Are the learners free to follow their own goals and interests?
- Does the facilitator demonstrate different possible outcomes to encourage personal and creative approaches?



## FIELD NOTES

Consider...

- What elements of the activity and the facilitation help engage students?
- Are the learners doing things like designing, testing, predicting, refining their ideas?
- What do you notice about the 'talk' in the room? Is the language technical or simple?



## LAJ FACILITATION

SKETCH THE ROOM LAYOUT INCLUDING POSITION OF TABLES, CHAIRS, TOOLS AND MATERIALS. OBSERVE ONE OR TWO STUDENTS FOR 5 MINS ONCE THE ACTIVITY HAS STARTED. SKETCH WHERE THEY MOVE FROM AND TO. FOCUS ON THE ATMOSPHERE. HOW ARE THE STUDENTS ENCOURAGED TO GET STARTED?

	NOTES
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## [B] FACILITATION

### USE THE CHECKLIST TO HELP OBSERVE TINKERING FACILITATION TECHNIQUES. HOW DOES FACILITATION HELP INCLUDE ALL STUDENTS?

#### DEEPENING

**Supporting learners to go further than they would on their own.**

- Encouraging learners to look at what others are doing.
- Encouraging risk-taking and experimentation.
- Suggesting further challenges.

#### SUSTAINING

**Supporting learners through frustration**

- Allowing thinking time before offering solutions.
- Offering suggestions rather than directions.
- Working together with the learner (collaborating).
- Answering questions with questions to guide thinking.

#### VALUING

**Valuing learners' experiences and interests and helping them feel these are valid.**

- Celebrating wonder, surprise, pride, joy.
- Showing enthusiasm about their ideas or personal goals
- Sharing learners ideas with others.
- Asking questions that encourage personal responses: e.g. „Have you ever seen...? Who has ever...? “

#### PERSONALISING

**Enabling the learning to link to personal experiences and interests.**

- Linking to outside interests.
- Using everyday world or personal experiences.
- Emphasising different possible approaches or outcomes e.g. -showing a range of example projects.

#### ENGAGING

**Helping all learners feel welcome**

- Guiding learners to find and use tools/materials
- Being enthusiastic, energetic and encouraging
- Meeting learners at eye-level.
- Making sure everyone feels welcome and comfortable.



## ICJ BROADENING WHAT COUNTS AS LEARNING: TINKERING LEARNING DIMENSIONS

LEARNING DIMENSIONS	EVIDENCE			WHAT DID YOU SEE OR HEAR?
	NONE	SOME	STRONG	
<p><b>Creativity and Self-expression</b>            Responding aesthetically to materials and phenomena            Connecting projects to personal interests and experiences            Playfully exploring            Expressing joy and delight            Using materials or tools in new or novel ways</p>				
<p><b>Problem solving and Critical &amp; Divergent Thinking</b>            Troubleshooting            Moving from trial and error to fine-tuning through increasingly focused inquiries            Developing work-arounds            Seeking ideas, assistance and expertise from others</p>				
<p><b>Social and Emotional Engagement</b>            Building on or remixing the ideas and projects of others            Teaching and helping one another            Collaborating and working in teams            Recognising and being recognised for accomplishments and contributions            Developing confidence            Expressing pride and ownership</p>				
<p><b>Conceptual Understanding</b>            Controlling for variables as projects complexity            Constructing explanations            Using analogues and metaphors to explain            Leveraging the properties of materials and phenomena to achieve goals</p>				
<p><b>Initiative, Intentionality, Resilience and Courage</b>            Setting personal long and short-term goals            Taking intellectual and creative risks            Persisting through and learning from failures            Adjusting goals based on physical feedback and evidence            Complexifying over time</p>				



## IDI STRUGGLE AND SUCCESS

### THINK ABOUT:

- ARE PROBLEMS AND FRUSTRATIONS WELCOMED AS AN IMPORTANT?
- HOW DOES THE FACILITATOR HELP LEARNERS WITHOUT PROVIDING THE SOLUTION?
- DO THE LEARNERS WORK WITH OTHERS TO SOLVE PROBLEMS IN A COLLABORATIVE WAY?
- WHERE THERE IS A STRUGGLE, WHAT SORTS OF SKILLS ARE DEVELOPED?

EXAMPLE OF STRUGGLE	EXAMPLE OF SUCCESS

## APPENDIX TINKERING LEARNING DIMENSIONS

© THE TINKERING STUDIO

### Initiative & Intentionality

- Setting one's own goal
- Taking intellectual and creative risks; working without a blueprint
- Complexifying over time
- Persisting through and learning from failures
- Adjusting goals based on physical feedback and evidence

### Problem Solving & Critical Thinking

- Troubleshooting through iterations
- Moving from trial-and-error to fine tuning through increasingly focused inquiries
- Developing work-arounds
- Seeking ideas, assistance, and expertise from others

### Conceptual Understanding

- Controlling for variables as projects complexify
- Constructing explanations
- Using analogues and metaphors to explain
- Leveraging properties of materials and phenomena to achieve design goals

### Creativity & Self-Expression

- Responding aesthetically to materials and phenomena
- Connecting projects to personal interests and experiences
- Playfully exploring
- Expressing joy and delight
- Using materials in novel ways

### Social & Emotional Engagement

- Building on or remixing the ideas and projects of others
- Teaching and helping one another
- Collaborating and working in teams
- Recognizing and being recognized for accomplishments and contributions
- Developing confidence
- Expressing pride and ownership



## Teacher Reflection Tool

What is your name? English - United Kingdom

Which museum or science centre did you visit with your students to watch Tinkering?

Think about the Tinkering experience you observed. In what ways was Tinkering valuable for your students? List **TWO** benefits.

Benefit 1

Benefit 2

To what extent do you think the following statements are true for your students when they took part in Tinkering? Please give a score out of 10 for each.

0 1 2 3 4 5 6 7 8 9 10

Students seemed engaged and interested

\_\_\_\_\_

It encouraged creative thinking

\_\_\_\_\_

It encouraged the students to think through problems for themselves

\_\_\_\_\_

Students could follow their own interest

\_\_\_\_\_

Students could work collaboratively

\_\_\_\_\_

It encouraged students to be innovative

\_\_\_\_\_

Will you speak with colleagues at school to share what you have learned about Tinkering?

Yes

Maybe

No

Do you think that you will do Tinkering with your students at school?

Yes

Maybe

No

Please explain your answer. For example, what Tinkering activity might you do? Or if you do not plan to do Tinkering, please explain why.

Look at your observation notes. Do you think that Tinkering was effective for engaging students facing disadvantage such as a disability, language barriers or socio-economic disadvantage?

Yes

No

Maybe

Please explain your answer. If you have one, please give an example of how Tinkering supported or engaged a student or students in your class who are facing disadvantage.



What evidence will you use to check if your plan is successful?

Teacher observation(s)

Interviewing students

Student survey

Student reflective diary (students write down their thoughts and ideas)

Other

For 'other', please explain:

Thank you for sending us your reflections, your responses will help us learn more about Tinkering as an approach for supporting learning in science.

Look your observation notes. Think about the elements of the Tinkering pedagogy - the **environment, activity or facilitation** - that you thought were effective. Perhaps you watched a facilitator using questions to help a learner think through a problem rather than give them a solution. Perhaps you saw students setting their own goals and being given time to follow their interest.

Describe **one feature of Tinkering pedagogy** that you would like to try out in your classroom in the box below.

Create a short action plan for implementing this feature of Tinkering pedagogy in your classroom - write down the things you will do to make it happen.

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