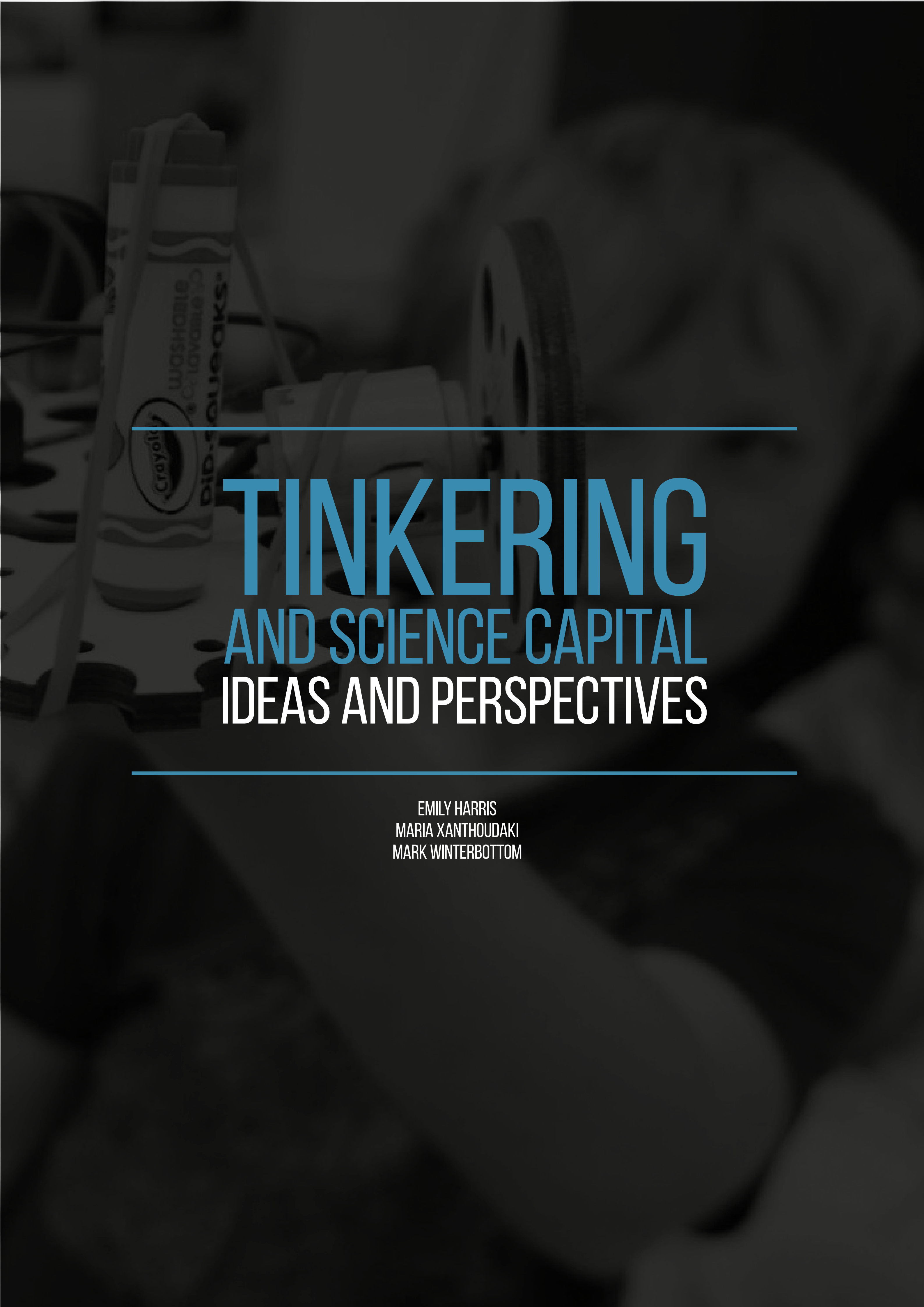

TINKERING
AND SCIENCE CAPITAL
IDEAS AND PERSPECTIVES

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Tinkering and Science Capital: Theoretical and Methodological Framework
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FORWARD

Pioneered in the United States and increasingly gaining recognition in Europe, Tinkering is an innovative learning approach, which builds on constructivism, constructionism and inquiry-based pedagogy and exploits some of the most engaging and motivational elements of learner-centred, personalised learning. This publication is the first output of the EU-funded project 'Tinkering EU: Building Science Capital foALL' which integrates Tinkering approach with some of the latest educational research in the area of 'Science Capital' with the aim to encourage engagement with STEM by students, especially disadvantaged groups, of 8 to 14 years (Erasmus+ 2017-1-IT02-KA201-036513, http://www.museoscienza.org/tinkering-eu2/).
The project is the continuation of "Tinkering: Contemporary Education for the innovators of tomorrow" funded by the Erasmus+ Programme (Erasmus+ 2014-1-IT02-KA200-003510, www.museoscienza.org/tinkering-eu). That project ran from 2014 to 2017 and introduced Tinkering in the European context. It reflected on the Tinkering approach as a way to support the development of 21st century skills for young people and adults and developed and implemented new Tinkering activities for informal science learning contexts.

Building on what was learnt during the first project, particularly in relation to successful implementation of activities with diverse audiences and working with schools to promote uptake, 'Tinkering EU: Building Science Capital for All' intends to reflect on the potential of Tinkering for engagement and learning in STEM, in particular by reflecting on the notion of 'Science Capital'. Research on Science Capital is providing insights into the reasons why some young people, especially those facing economic, social and cultural disadvantage have low participation rates in STEM both in and out of school and do not aspire to study STEM or to pursue scientific careers. The project will bring together museums and schools to support students facing disadvantage, to raise their STEM identity and to help them build transferable 21st century skills.

The project emerges from the following challenges facing contemporary global society:

- **1/Active citizenship** is essential for tackling major contemporary challenges in society: for example, issues arising from differences in race, religion or culture, access to sustainable livelihoods, health and educational opportunities, democratic participation, social exclusion and equal opportunities for women (British Council, 2014). 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 are capable of building the knowledge and skills necessary for creating active citizens.

- **2/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. Despite efforts, however, the situation is little improved: approaches to science education are failing to engage young people and STEM skills gaps are widening in Europe, indicating that schools cannot bear the task alone.

- **3/Science engagement** in school is particularly problematic for young people with learning difficulties, poor school performance and for young people from ethnic minorities or 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 most effectively, especially for those facing disadvantage, we need to improve school practice by adopting new approaches to science education that favour student-centred pedagogies. This project responds to the above needs through the application of Tinkering to develop a learner-centred culture in and out of school and to develop 21st century skills which support active citizenship, employability and social inclusion.

The project has a strong social justice agenda and is framed by the Science Capital educational theory. Science Capital is an emerging and increasingly widely recognised area of science education research and practice. Inspired by the work of Pierre Bourdieu on reproduction of social inequalities, science capital pedagogy promotes equity and social justice in science (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; Godec, King, & Archer, 2017).
It emphasizes the need for science education practitioners to take into account the broad set of influences and experiences that impact STEM participation and aspirations beyond compulsory STEM in school in order to better understand where inequalities lie and how these can be overcome through more student-centred teaching and learning approaches.

To help achieve its aims, the project will draw upon the expertise of science museums.
Already key players in educational change, science informal learning institutions are widely recognized for adopting approaches that place the individual at the centre of the learning process and create meaningful, personalised, lifelong relationships between individuals and science (Black, 2006; Brahms & Werner, 2013; DCMS & DfEE, 2000; Dierking & Falk, 1994; Hein, 1995; Hooper-Greenhill, 2008; Mayfield, 2005; Mortensen & Smart, 2007; Shouse, Lewenstein, Feder, & Bell, 2010; Silverman, 1995).

Museums and schools are institutions with complementary educational missions, working together to create a 'learning ecosystem' that builds knowledge and skills useful for a lifetime. At the same time, science museums set social justice as part of their mission, caring for underserved communities and fostering science literacy amongst all sectors of the population.

The project focuses on building engagement with, and participation in, STEM for young people identified as having relatively low levels of Science Capital and who are therefore less likely to be engaged with science in school, to choose to pursue science study beyond compulsory schooling or to participate in science-related activities out of school.

PROJECT OVERVIEW

Working with students from 8 to 14 years old (primary and junior high schools) and their teachers this project aims to:

- help build the dimensions of science capital for young people through participating in Tinkering, particularly those identified as having relatively low levels of science capital;
- influence teaching and learning to increase equity in STEM learning.

In order to achieve these aims the project will:

Explore the use of 'Tinkering' with young people facing economic, social and cultural disadvantage. Tinkering is a highly inclusive, innovative educational approach used by museums to promote lifelong engagement with science for diverse audiences. Tinkering can be particularly effective for helping to engage individuals who think that 'they are not good at science' or who are disaffected with formal teaching and learning processes. Its inclusive nature means that Tinkering can be a powerful tool to tackle disadvantage.

Work collaboratively with teachers to integrate Tinkering into the science curriculum. This will be achieved through museum visits for young people that will introduce Tinkering in a hands-on, inspiring way, as well as through teacher training workshops aimed at supporting teachers to develop the Tinkering, and the pedagogical features of tinkering in their own practice.

DOCUMENT OVERVIEW

This document provides a theoretical rationale for understanding the relationship between Tinkering as a pedagogical approach, students' individual science capital, and inclusive STEM teaching approaches. By exploring the relationship between these three areas, it invites professionals to reflect on the ways in which Tinkering can be used a teaching tool for building science capital.

SECTION 1
STEM EDUCATION AND SOCIAL JUSTICE

The first section discusses the increasing STEM skills gap in Europe and highlights the social justice agenda for engagement with STEM for all students, but particularly those facing disadvantage.

SECTION 2
SCIENCE CAPITAL: A FRAMEWORK FOR UNDERSTANDING PARTICIPATION AND ASPIRATIONS IN STEM

Section 2 introduces and explains current science capital educational research theory, how this relates to practice and its theoretical application for this project.

SECTION 3
TINKERING: INCLUSIVE STEM PRACTICE THROUGH PERSONALLY MEANINGFUL LEARNING EXPERIENCES

Using work carried out during the first EU project, this section provides a thorough explanation of Tinkering pedagogy, examples of 'tried and tested' activities, methods of facilitation and the dimensions of learning developed through Tinkering pedagogy.

SECTION 4
JOINING IT UP: TINKERING AND BUILDING SCIENCE CAPITAL FOR ALL

The fourth section explores the relationship between Tinkering and science capital, drawing together learning features of both areas and demonstrating the synergies that should catalyse powerful learning experiences for disadvantaged young people, as well as help teachers to engage students in personally meaningful STEM learning with the aim of increasing aspirations and participation in STEM for disadvantaged learners.

INDEX

1

STEM EDUCATION AND SOCIAL JUSTICE

1.1 PATTERNS OF INEQUALITY AND UNDER-REPRESENTATION IN STEM

1.1.1 ECONOMIC AND INDIVIDUAL DRIVERS FOR INCREASED PARTICIPATION IN STEM FOR UNDER-REPRESENTED GROUPS

THE STEM SKILLS GAP

Diversity in STEM education and careers is high on the European political agenda. Over the last decade recruitment into the STEM sector has been of increasing concern as the proportion of STEM graduates declines and the STEM skills gap widens. As an example, the EU is facing an estimated shortfall of 800.000 skilled workers for Information Communication Technology posts (ICTs) by 2020 (European Commission, 2007). The economic and political case for increased diversity and participation in STEM is clear. Workforce undersupply is a worrying trend, especially when comparing Europe with regions such as South Asia, which has high numbers of STEM graduates and good retention of these graduates into STEM careers.

STEM, SOCIAL JUSTICE AND ACTIVE CITIZENSHIP

Beyond the economic case for diversity in STEM, there are many personal and social benefits in relation to STEM participation and learning. Scientifically literate citizens are better able to utilise beneficial science resources, for example, in relation to health and technology. They are also more likely to participate actively in democratic processes relating to science in society. Those taking STEM subjects beyond compulsory schooling and a degree level are more likely to have higher earning jobs and, as such, STEM participation beyond school also represents a route to social mobility (Greenwood, Harrison, & Vignoles, 2011).

For these reasons, the European Union has spent more than a decade trialling interventions aimed at increasing interest and participation in STEM. These have been largely, but not solely, school-based and include new and improved pedagogical approaches for STEM lessons, giving students a better understanding of the relevance of STEM to life, engaging students in awareness-raising activities around STEM jobs, and organising STEM fairs (Joyce, 2014).

1.1.2
DISPARITIES IN STEM PARTICIPATION AND ASPIRATIONS

Longitudinal research is indicating that while efforts to increase interest in school STEM may indeed have positive gains in terms of student engagement and enjoyment, this does not necessarily impact the STEM pipeline (DeWitt & Archer, 2015): the STEM skills gap continues to widen and patterns of inequality persist. Socio-Economic Position (SEP), gender and ethnicity are all associated with post-school STEM participation (Codiroli, 2015). Women, people with disabilities and those from ethnic-minorities or socially-disadvantaged groups are consistently underrepresented, particularly at senior levels, in STEM jobs (CaSE, 2014). In school, attainment in STEM and aspiration for STEM study beyond school or STEM careers are not necessarily aligned. Several multi-partner, pan-European and international project have demonstrated that despite most students reporting that science lessons are 'fun' and agree that STEM is important for society, the majority of students, and particularly girls, do not aspire to STEM careers (Gallup Organisation, 2008; Kudenko & Gras-Velázquez, 2016; Sjøberg & Schreiner, 2010).

A growing body of literature is exploring the complex reasons behind patterns of attainment and participation in STEM with implications for policies and interventions aimed at increasing equity and social mobility. Ascertaining the relative influence and interaction of different variables for different groups is complex. For example, research indicates that some variables, including parental influence and SEP, have differing levels of impact on boys and girls and across different ethnic groups (Codiroli, 2015). The dominant view that engagement and participation in STEM is governed by interest is being challenged.

There is evidence that streaming and setting students in STEM serves to widen the STEM participation gap because it increases the attainment gap, and prior STEM attainment is an influencing factor for subject choice post-16. Children from low SEP backgrounds, ethnic minorities and boys are more likely to be placed in low ability groups (Hallam & Parsons, 2013; Parsons & Hallam, 2014), however, the benefits of positive peer-grouping are only found in top sets and so the practice of setting widens the gap between the top and bottom tiers without raising average attainment (Parsons & Hallam, 2014). One longitudinal UK study demonstrated that Black Caribbean students are significantly under-represented in higher tier sets after controlling for factors including prior attainment, truancy, special needs, SEP and maternal education (Strand, 2007). Research is also indicating that while many students enjoy doing science in school, this interest and enjoyment does not necessarily translate into post-16 STEM study or aspirations for a STEM job (Archer et al., 2010; DeWitt & Archer, 2015). Recent research around the notion of science capital is exploring factors that could influence personal conceptions of identity and whether or not young people see science as something that is 'for me' (DeWitt & Archer, 2015; DeWitt, Archer, & Mau, 2016), as well as specific interventions in school with teachers that might be most effective for increasing equity in STEM (King & Nomikou, 2017).





2

SCIENCE CAPITAL: EXPLAINING PARTICIPATION AND ASPIRATIONS IN STEM

2.1 SCIENCE CAPITAL AS AN EMERGING CONCEPTUAL FRAMEWORK

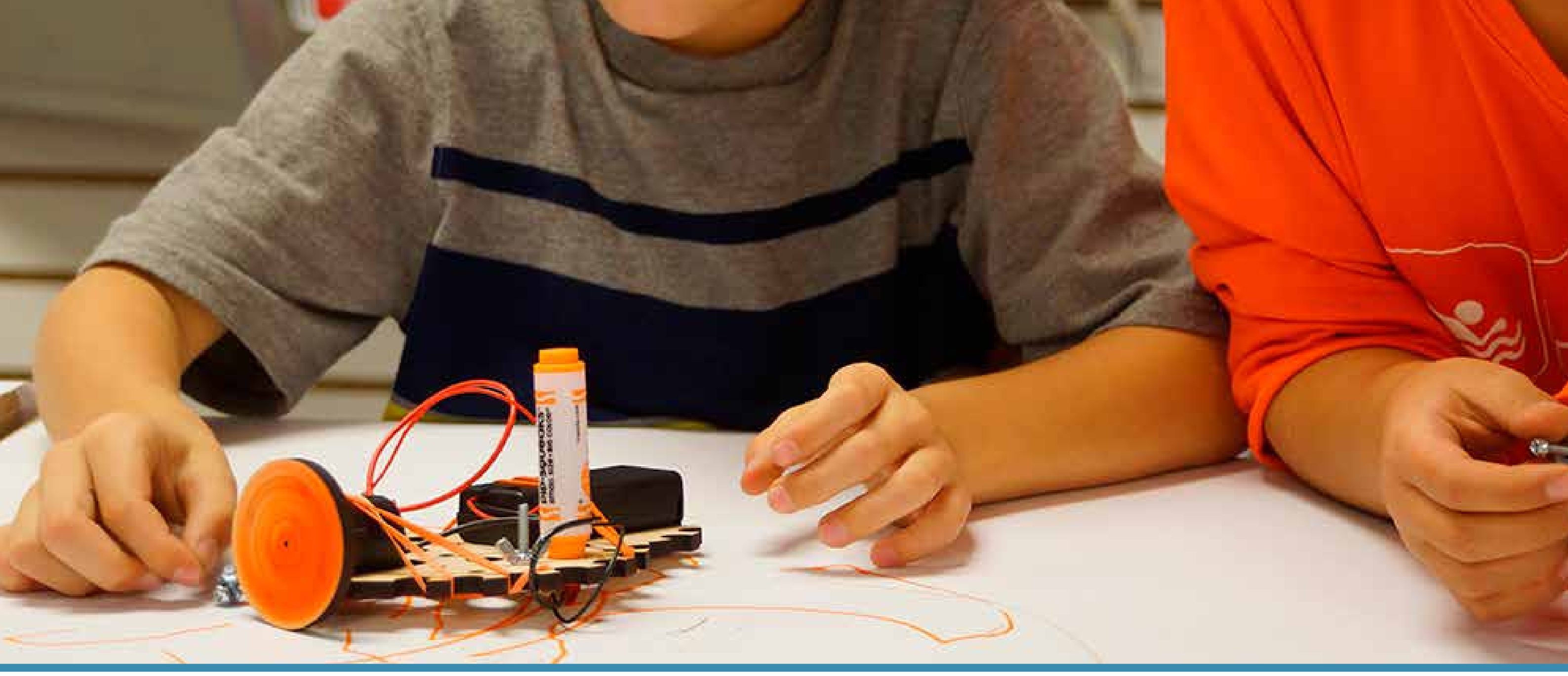
Over the last decade, the ESRC-funded the 10-year longitudinal ASPIRES project. The subsequent ASPIRES2[1] and Enterprising Science projects collected and analysed survey data from 3.658 school students aged 10-19 years alongside interviews with students, teachers and parents to explore influences of family, school, careers education, social identities and inequalities on young people's science and career aspirations. A key survey finding was that although most children indicated that they found science interesting, only 15% of 10-14 year olds were interested in becoming a scientist. When the team delved deeper to gather a more detailed picture for individual students about what was happening in their lives outside of school, they found broad-ranging influences and experiences interacting to shape students' science identity and STEM aspirations. These influences have since been developed into 'Science Capital Dimensions Framework', which is explained in more detail in section 2.2.1.

Based on the findings from this research and building upon work by Bourdieu, the ASPIRES team proposed the notion of 'Science Capital' as a 'theoretical lens for explaining different patterns of aspiration and educational participation in STEM among young people' (Archer et al., 2012; Archer, DeWitt, & Willis, 2013). At its simplest level, Science Capital can be understood as a measure of an individual's science-related resources as well as their attitudes and ways of thinking.

The analogy that the UK researchers use is that of a bag that you carry around through life containing your science-related knowledge (what you know), attitudes (what you think), experiences (what you do) and contacts (who you know) with a hypothesis that this bag does not have fixed contents - the contents can be added to as you move through life (Archer, Dawson, DeWitt, Godec, et al., 2015; Archer, Dawson, DeWitt, Seakins, et al., 2015; DeWitt et al., 2016).

Research to explore the idea of science capital is on going and was a main focus of the Enterprising Science project, which worked with teachers to explore the concept of science capital as a pedagogical approach in the classroom.

The UK-based research as part of ASPIRES and Enterprising Science has stimulated a discussion on the role and value of science capital which goes beyond the specific contexts or the UK. Science capital is increasingly being adopted across formal and informal STEM learning as a framework to help teachers and informal learning practitioners better understand why STEM learning experiences may resonate better with some young people's lives and experiences than others. It therefore serves as a conceptual tool to help explain why and how STEM teaching and learning approaches, both in and out of school, can be adapted so that they value and connect with the life experiences and interests of a broader range of students than those with existing high levels of science capital (Archer, Dawson, DeWitt, Godec, et al., 2015; DeWitt et al., 2016; Godec et al., 2017). This way of thinking about STEM teaching is being developed collaboratively by UK teachers and researchers into a 'Science Capital Teaching Approach', which is explored in more detail in section 2.3.



2.2
SOCIOLOGICAL CONTEXT: SCIENCE CAPITAL AND BOURDIEU

The concept of science capital is based on work by Bourdieu, which looks at how inequalities arise and are reproduced in society. Bourdieu's ideas on education and social inequality have been extremely influential in educational research. Bourdieu argues that privilege and power in society are determined by a dynamic, two-way relationship between three social dimensions:

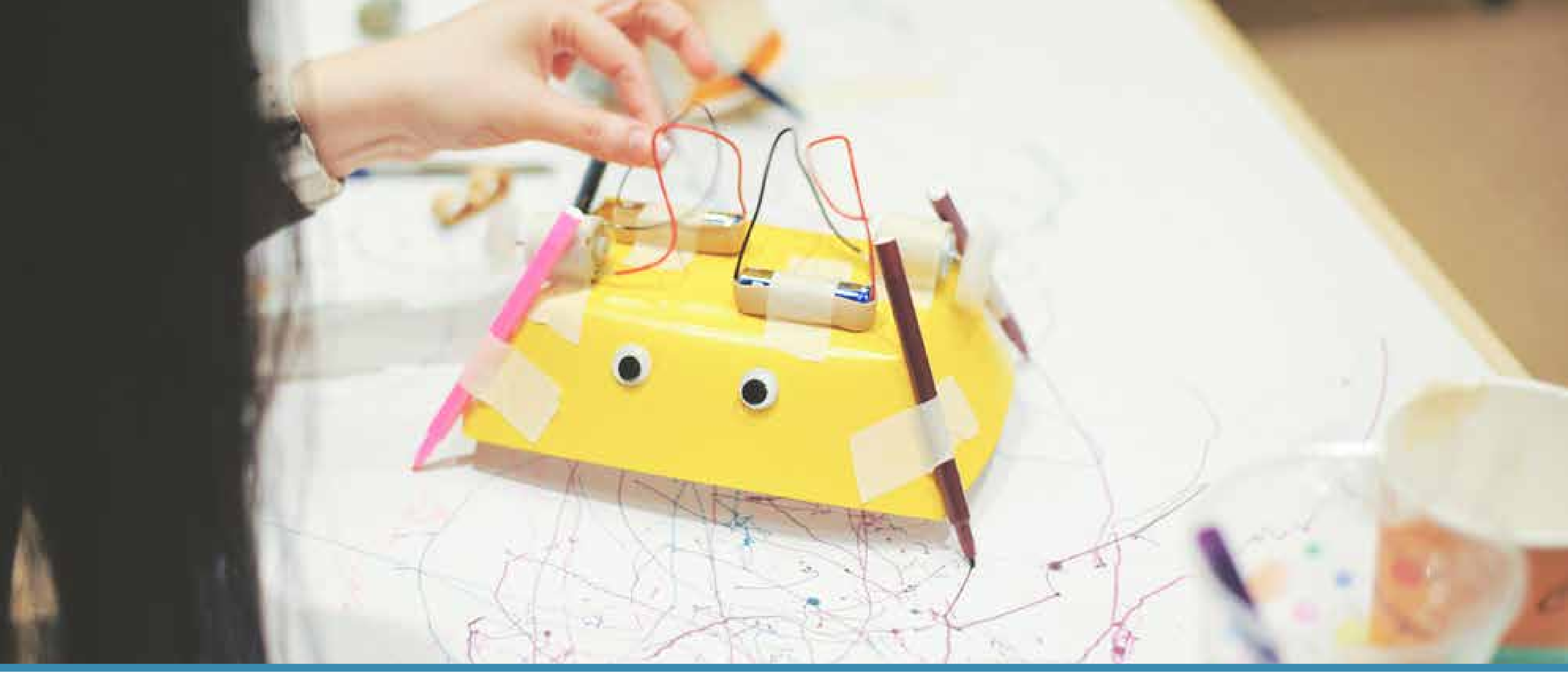
1/Habitus our unconscious predispositions, orientations and habits, which are shaped by our social and cultural life and which determine how we perceive, appreciate or behave in the social world.

2/Capital the assets or resources that people variably posses that can confer social advantage. These forms of capital can be economic, cultural, social or symbolic (Figure 1).

3/Fields distinct but sometimes overlapping social domains (e.g. art, religion, law, education), each with its own set of 'rules of the game' and competition as people use their capital to compete and gain position within that domain. To use Bourdieu's analogy, those with higher capital wit hin a field will move through it more like a 'fish in water' than a fish out of it (Bourdieu & Wacquant, 1992).

FIGURE 1 / BOURDIEU'S FOUR FORMS OF CAPITAL

BOURDIEU'S FORMS OF CAPITAL		Summary
ECONOMIC CAPITAL		Financial assets, wealth
CULTURAL CAPITAL	INSTITUTIONALISED CULTURAL CAPITAL	Academic qualifications, credentials and skills.
	OBJECTIFIED CULTURAL CAPITAL	Material objects (such as books, paintings, instruments or equipment) that are valuable not only because they signify various things about their owners, but also because their owners can use them to enrich their cultural capital.
	EMBODIED CULTURAL CAPITAL	Your dispositions (e.g. language, dialect, how you think and perceive, your habits etc.) that are transmitted from early childhood from parents to children and are a crucial factor in determining academic success. they create desire for institutional capital in the form of qualifications such as a degree from a high-status university as well as for material objects that have cultural capital, and also enable the young person to make use of theml.
SOCIAL CAPITAL		The advantage you can gain from your utilisable networks and social connections.
SYMBOLIC CAPITAL		The degree to which any form of capital is given credence, recognition or value. Some have also interpreted symbolic capital as the resources available to you as a result of honour, status, prestige or recognition.



Bourdieu argues that social inequality is legitimised and reproduced by education systems in industrial society because these systems assume possession of cultural capital, which varies with social class (Sullivan, 2002). What Bourdieu is saying, in effect, is that our education systems, our curricula and assessments, are rigged to favour those with high cultural capital, who will be those from wealthier families and with better access to objectified cultural capital and other forms of capital. It is within this context that the notion of science capital was developed. Importantly, The UK Science Capital Research Team do not view science capital as another, different form of capital. They argue that science capital comprises all of the science-related forms of social and cultural capital, and that the notion of science capital helps enable science researchers and practitioners to look at the workings of science related aspects of cultural and social capital in a more focused way.

2.2.1 FORMS OF SCIENCE-RELATED SOCIAL AND CULTURAL CAPITAL: WHAT DO THEY LOOK LIKE?

Figure 2 provides an overview of the forms of science capital that emerged and were refined through the process of developing the survey tool used in the ASPIRES project (Archer, Dawson, DeWitt, Seakins, et al., 2015). Further analyses of data as part of the Enterprising Science project resulted in an eight-dimension model, shown in Figure 3.

FIGURE 2 / COMPONENTS OF AN INDIVIDUAL'S SCIENCE CAPITAL. ADAPTED FROM (ARCHER, DAWSON, DEWITT, SEAKINS, ET AL., 2015)

FORMS OF SCIENCE CAPITAL	DIMENSIONS	MEASURES/INDICATORS	DEPENDENT VARIABLES: CHARACTERISTICS THAT SCIENCE CAPITAL WILL IMPACT
1 **SCIENCE-RELATED FORMS OF CULTURAL CAPITAL**	Scientific literacy	• Their level of scientific conceptual knowledge and scientific skills. • Their understanding of 'how science works'. • Their ability to use and apply science knowledge and skills in everyday thinking and life.	**FUTURE SCIENCE AFFINITY** future science educational and career aspirations - their intention to study science further or to go onto a science - related career.
	Scientific-related dispositions, preferences and values	• Their attitudes toward science, scientists, school science. • The value they place on science in their life.	
	Symbolic knowledge about the transferability of science	• The degree to which they understand that science qualifications are transferable in the labour market i.e. knowing that science can open doors to many different job opportunities and not just in science.	
2 **SCIENCE-RELATED BEHAVIOURS AND PRACTICES**	Consumption of science-related media	• The extent to which they engage with science-related media forms e.g. TV programmes, books, magazines, and online sites.	
	Participation in out-of-school science learning contexts	• Their level of participation in and engagement with informal science learning activities e.g. visits to science centres/museums, belonging to after-school clubs, etc.	**SCIENCE IDENTITY** the extent they themselves as being 'scientific' – do they see themselves as a 'sciencey' person?
3 **SCIENCE-RELATED FORMS OF SOCIAL CAPITAL**	Knowing someone who works in a science job	• The extent to which their social network contains scientists and 'sciencey' people.	
	Parental science qualifications	• The influence that having science-qualified parents has on their aspirations to go into science-related careers themselves.	
	Talking to others about science	• The types, nature and frequency of conversations they have with friends, family, teachers and other people in their social network about science.	

FIGURE 3 / EIGHT DIMENSIONS OF SCIENCE CAPITAL (GODEC ET AL., 2017)

DIMENSIONS OF SCIENCE CAPITAL	DEFINED BY...
1 SCIENTIFIC LITERACY	A young person's knowledge and understanding about science and how science works. This also includes their confidence in feeling that they know about science.
2 SCIENCE-RELATED ATTITUDES, VALUES AND DISPOSITIONS	The extent to which a young person sees science as relevant to their everyday life.
3 KNOWLEDGE ABOUT THE TRANSFERABILITY OF SCIENCE	Understanding the utility and broad application of scientific skills, knowledge and qualifications.
4 SCIENCE MEDIA CONSUMPTION	The extent to which a person, engages with science-related media including television, books, magazines and internet content.
5 PARTICIPATION IN OUT-OF-SCHOOL SCIENCE LEARNING CONCEPTS	How often a young person participates in informal science learning contexts, such as science museums, science clubs and fairs.
6 FAMILY SCIENCE SKILLS, KNOWLEDGE AND QUALIFICATIONS	The extent to which a young person's family have science-related skills, qualifications, jobs, and interests.
7 KNOWING PEOPLE IN SCIENCE-RELATED JOBS	The people a young person knows (in a meaningful way) among their wider family, friends, peers, and community circles who work in science-related roles.
8 TALKING ABOUT SCIENCE IN EVERYDAY LIFE	How often a young person talks about science with key people in their lives (friends, siblings, parents, neighbours, community members).

2.2.2
SCIENCE CAPITAL: PREDICTING PARTICIPATION, CATALYSING INCLUSION

The original science capital survey developed through the Enterprising Science Project comprises 80 questions and takes 20-40 minutes to complete. Scores are calculated through statistical analysis of responses. Researchers from the Enterprising Science project are still developing these survey tools to explore changes in science capital over time (e.g. after participation in a particular project or programme). But the researchers state that these are relatively blunt tools and should be used to complement qualitative approaches (Archer, Dawson, DeWitt, Godec, et al., 2015). There is increasing consensus that while small-scale interventions are unlikely to show significant changes in science capital scores, quantified measures of science capital can be used to predict career progression into science as well as participation in science more broadly: for example, in informal science learning activities.

The "Tinkering EU: Building Science Capital for ALL" project recognises that science capital holds great value for educational practitioners in its explanatory capacity because an understanding of science capital can help practitioners reflect on their own STEM pedagogy (Archer, Dawson, DeWitt, Godec, et al., 2015; King & Nomikou, 2017). Science capital as a concept demonstrates that many components combine and interact to shape and influence a young person's confidence, attainment, attitudes and aspirations in STEM, both in and out of school.

By helping practitioners understand the different components of science capital we might help them better appreciate the varied backgrounds and experiences of their students, and the relevance of this for developing more inclusive teaching practice. Reflecting on the dimensions of science capital can help practitioners better understand why existing school STEM experiences connect better with the lived experiences of some students than others and therefore why some young people feel less comfortable and 'in-tune' with formal STEM teaching and learning than others (Archer, Dawson, DeWitt, Godec, et al., 2015; King & Nomikou, 2017). This can then help shift the pedagogical teaching and learning narrative toward new STEM education approaches that engage a broader range of students by valuing a wider range of individual interests and experiences and by linking STEM learning to these. This idea is at the heart of the newly articulated Science Capital Teaching and Learning Approach outlined in section 2.3.

2.3 SCIENCE CAPITAL IN PRACTICE: THE SCIENCE CAPITAL TEACHING APPROACH

2.3.1 WHAT IS THE SCIENCE CAPITAL TEACHING APPROACH?

In October 2017[3] and March 2018[4], the UK SC Research Team ran two national teacher professional development events which introduced the Science Capital Teaching Approach (Godec et al., 2017). The approach was co-developed with 43 science teachers between 2013 and 2017 as part of a series of action research projects which:

- explored how to make science more meaningful and relevant for students from diverse and disadvantaged backgrounds;
- trialled initial ideas and approaches in lessons;
- developed approaches which could be incorporated into existing schemes of work;
- implemented these approaches and looked for the impact on student interest, attitudes and attainment.

The approach does not introduce a new curriculum or sets of materials, but rather suggests ways of contextualising STEM in the classroom so that it i) better connects with, and ii) deeply and genuinely values the current, personal lived experiences of students. The idea is that the approach builds on good teaching practice which ignites student interest and engagement in science through 'an explicit focus on recognising and valuing students' existing science capital whilst also helping them to build new capital' (Godec et al., 2017).

So a science capital teaching approach goes beyond general context for STEM learning and tries to find a personal context in which to frame or hook the learning. In other words, educational practitioners should aim for STEM learning to connect directly with what students do, places they go, people they talk to, things they enjoy or things they talk about outside of school in the here and now.

2.3.2
THE THREE PILLARS MODEL FOR SCIENCE CAPITAL AS A TEACHING APPROACH

The Science Capital Teaching Approach has been summarised by the UK team as a three-pillars model shown diagrammatically in figure 4 and explained in more detail in figures 5 and 6.

Of particular importance for appreciating the approach is the centrality of valuing learner's personal, lived experiences within the STEM classroom.

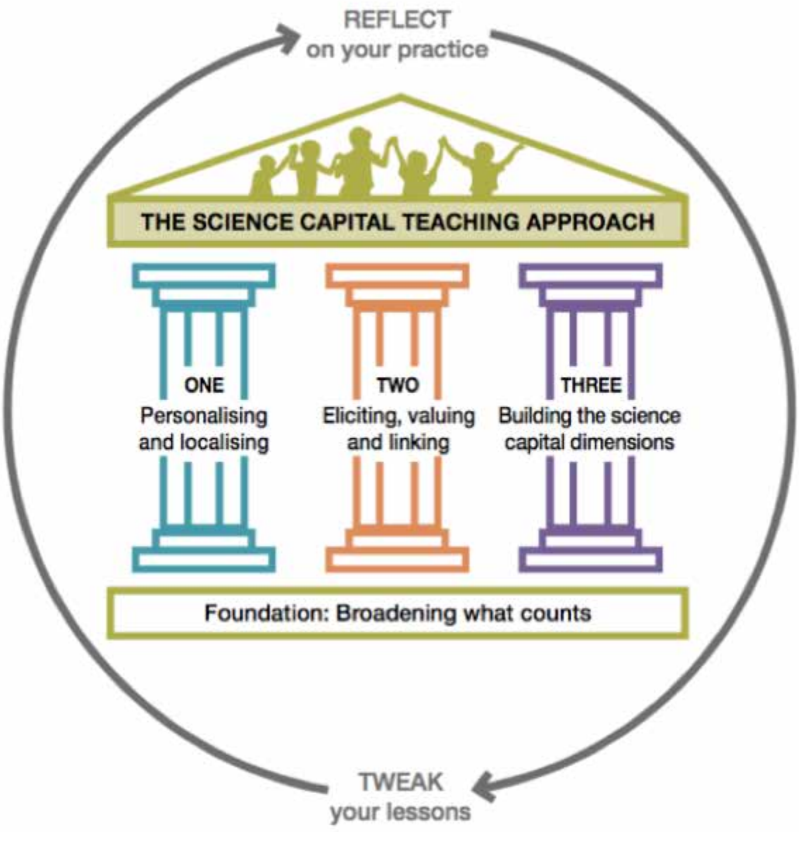


FIGURE 5 / THREE PILLARS MODEL FOR UNDERSTANDING THE SCIENCE CAPITAL TEACHING APPROACH. ADAPTED FROM GODEC ET AL. (2017)

	WHAT	HOW?
FOUNDATION **BROADENING WHAT COUNTS**	• A teaching mind-set that recognises a broad range of experiences, skills and behaviours as having a legitimate place in the science classroom. • Learning environments where all students feel able to offer contributions from their own experiences, interests and identities.	• Establishing classroom ground rules where all contributions are welcomed and respected. • Making sure that certain students do not dominate. • Creating opportunities to express themselves in ways that they feel comfortable. • Highlighting the scientific nature of student contributions. • Talking about different types of people who work in science –related jobs. • Broadening students' views of what counts as doing science in the classroom so that curiosity, questioning, sharing experiences and relating science through personal experience are valued. • Challenging stereotypes that science is for certain sorts of students.
PILLAR 1 **PERSONALISING AND LOCALISING**	• Helping students to see that their interests, attitudes and experiences at home and in their communities relate to aspects of science. • Helping students to understand that they have resources that are valued in science.	• Creating lesson content that builds from students' interests, aspirations, local community life and life experiences. • Using examples and settings that are familiar and local to students as 'hooks' into the science content.
PILLAR 2 **PERSONALISING AND LOCALISING**	• Using questions to elicit students' knowledge that draws on personal, family and/or cultural experiences. • Explicitly recognising and acknowledging student contributions that come from the everyday lives of students to emphasize that such knowledge is relevant and worth sharing. • Connecting these contributions and lived experiences to appropriate aspects of the curriculum.	• Explicitly inviting students to think about and share their own lived experiences. • Using open questions. • Sharing relevant examples from their personal life experiences to create an environment where all sorts of contributions are valid. • Following up on student comments and deeply valuing them – recognising that these come from personal interest and may be of relevance to others in the class.
PILLAR 3 **BUILDING THE SCIENCE CAPITAL DIMENSIONS**	• Addressing the eight science capital dimensions across and throughout lessons.	SEE FIGURE 6

FIGURE 6 / IDEAS FOR INCORPORATING THE DIMENSIONS OF SCIENCE CAPITAL CAN BE INCORPORATED INTO SCIENCE TEACHING. FROM GODEC ET AL., (2017)

SCIENCE CAPITAL DIMENSIONS	IDEAS FOR HOW TO BUILD THE DIMENSION OF SCIENCE CAPITAL IN STEM LESSONS
1 SCIENTIFIC LITERACY	• Supporting students' understanding of science and how science works.
2 SCIENCE-RELATED ATTITUDES, VALUES AND DISPOSITIONS	• Discussing the value of scientific developments and the role science plays in society and the local community. • Talking about the use and misuse of scientific evidence in everyday life – from marketing claims to climate change. • Emphasizing that a diverse range of people use science skills and applications – (e.g. enquiry skills, creativity and analytical skills) in all sorts of activities.
3 KNOWLEDGE ABOUT THE TRANSFERABILITY OF SCIENCE	• Highlighting science skills involved in the varied jobs to which students might aspire e.g. framing analytical skills as useful in business, law ad journalism as well as in everyday like for making financial decisions.
4 SCIENCE MEDIA CONSUMPTION	• Encouraging students to watch science documentaries on TV or online or to read science-related news. These could be discussed in lessons.
5 PARTICIPATION IN OUT-OF-SCHOOL SCIENCE LEARNING CONCEPTS	• Pointing students to local (free if possible) science learning opportunities, arranging a school visit, asking students about out of school activities and places where they encounter science. • Maintaining an up-to-date 'what's on' calendar where students can also list activities. • Asking students about their tinkering, repairing, crafting or artistic habits at home and linking these with lesson content where applicable.
6 FAMILY SCIENCE SKILLS, KNOWLEDGE AND QUALIFICATIONS	• Supporting students to find and recognise any science skills and knowledge that their family members might use in their jobs or daily lives (note: the jobs do not have to be science-related).
7 KNOWING PEOPLE IN SCIENCE-RELATED JOBS	• Introducing students to people who work in science-related professions – if possible these interactions should be repeated and involve people with whom the students can relate (for example, people who grew up in that area, from similar cultural background). • Arranging for STEM ambassadors to visit the school. • Arranging for A-level science students to talk with younger students and share their experiences of studying post-16.
8 TALKING ABOUT SCIENCE IN EVERYDAY LIFE	• Setting homework tasks that encourage talking with family or peers about science. The aim is to normalise science talk outside of the classroom.

2.3.3
PROMOTING SOCIAL JUSTICE, ALTERING THE FIELD

With a strong social agenda, the Science Capital Teaching Approach recognises that students facing economic, social or cultural disadvantage are frequently, albeit not intentionally, excluded from traditional STEM learning environments. Educators' expectations can be subtly biased to exclude students who may not have the advantages of relatively higher socio-economic position – advantages such as a computer or phone with internet access at home to explore scientific videos and programmes set for homework, a safe and quiet place to study and complete homework tasks, fluency in the native language (thus familiarity with STEM language), working parent(s) above the poverty line, and access to learning opportunities in informal STEM setting such as science museums. When teachers do not take these disadvantages into account, the STEM classroom can inadvertently increase inequality of opportunity rather than break through it.

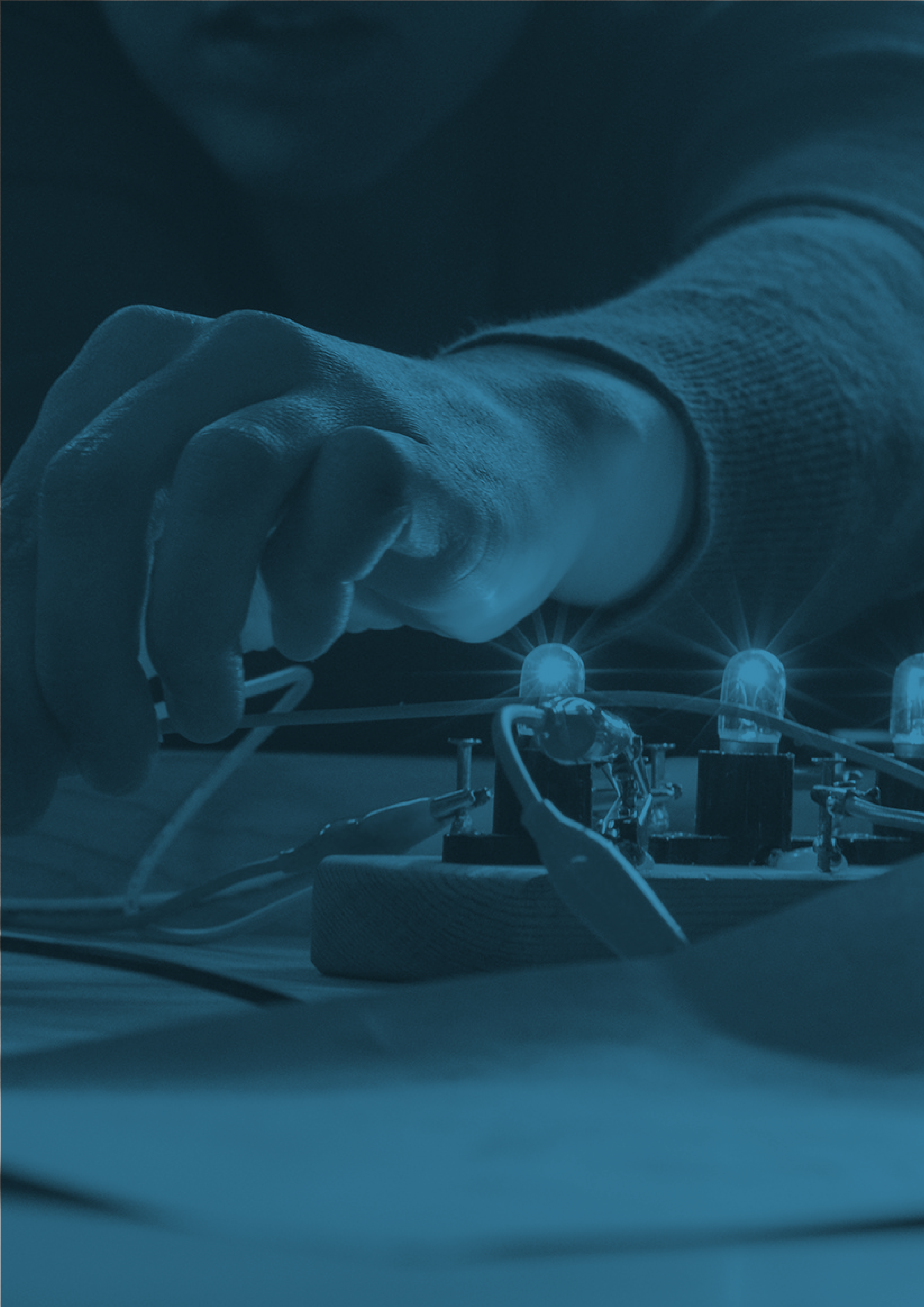
For this reason, a key aim of the Science Capital Teaching Approach is about altering the field in which students learn, thinking about the learning environment and teachers' attitudes and teaching style, in order to make them fundamentally more inclusive. Although an important element of the model is an attempt to build students' science capital by incorporating elements of the eight dimensions into lessons (as described in figure 6), the approach also emphasizes the importance of valuing and utilising students' existing resources:

"...the task of science education interventions may not be to provide students with 'more' or 'better' science capital, but may instead need to focus on shifting relations within/across particular fields to better enable activation of facilitating forms of capital... If the value of science capital lies in the processes that make it valuable, then perhaps the key task for science educators is to act on these to create contexts within which different forms of (science) capital are valued, activated, and able to be converted into symbolic forms of capital."

(Archer, Dawson, DeWitt, Seakins, et al., 2015)

As will be discussed in more depth in sections 3 and 4, it is perhaps here that Tinkering has the most potential for tackling disadvantage and developing science capital. Tinkering provides myriad opportunities for linking to students' existing forms of capital as well as for building more science-related forms of capital. And by adopting Tinkering in their practice, teachers are building the foundations for a science capital teaching approach because they are 'broadening what counts' as science and ways of learning science in their classroom.

Connections between Tinkering and science capital are explored in more depth in section 4, after a brief but comprehensive summary of Tinkering as a pedagogical approach in section 3 which draws directly from the work of the initial EU Tinkering project, 'Tinkering: Contemporary Education for Innovators of Tomorrow'.



3

TINKERING: INCLUSIVE STEM PRACTICE THROUGH PERSONALLY MEANINGFUL LEARNING EXPERIENCES

3.1 TINKERING: HISTORICAL AND EDUCATIONAL CONTEXT

3.1.1 BIRTH OF TINKERING

Tinkering has emerged over the last decade from the successful 'Maker Movement' which celebrates do-it-yourself (DIY) and do-it-with-others (DIWO) making practice through artisan crafts and emergent technologies using physical and digital resources (Brahms, 2014). Making is typically characterised by people coming together to create, collaborate and innovate using diverse tools, materials, ideas and methods. Materials used in making activities can be bought, salvaged, scavenged or donated and outcomes are highly diverse ranging from customised jewellery to cutting-edge robots.

In recent years, informal science learning institutions, particularly in the USA, have been implementing new maker-focused science education programmes (Honey & Kanter, 2013) with the aim of supporting people to explore scientific phenomena directly through playful, immersive, creative, physical activities that are learner-centred and driven by the individual's motivations and personal interests (Anzivino & Wilkinson, 2012; Brahms, 2014; Brahms & Werner, 2013).

The Exploratorium of San Francisco, the special advisor to this project, is the key player in this field. They have been developing, testing and refining making-based 'Tinkering' activities for visitors since 2008. The Exploratorium has a dedicated Tinkering space (The Tinkering Studio) which is a hands-on space where visitors are invited to investigate, experience and explore scientific phenomena through carefully designed making activities using a range of tools, materials and technologies. Through their work, the Tinkering Studio team have been developing the Tinkering methodology as a STEM-rich branch of making which emphasizes creative problem solving, thinking with your hands and learning through iterative design and testing (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Petrich & Wilkinson, 2013).

3.1.2
TINKERING AND EDUCATIONAL PEDAGOGY

There are several educational pedagogies that underpin Tinkering as a teaching and learning approach. Tinkering is highly constructivist in nature because it supports the learner in building their own understanding of scientific ideas and phenomena. By planning, designing, making, testing, and refining in a personal process of creating something new, the learner draws on their prior knowledge, creates connections between different existing ideas and concepts, and builds new understanding which is synthesised into their existing mental models.

Tinkering is also closely aligned with inquiry-based approaches for learning in STEM. Tinkering activities challenge the learner to develop their own questions and challenges, discuss ideas, recognise and articulate problems that they meet along the way, look for solutions, evaluate progress, hypothesise, test and re-test in a learning journey which can have multiple outcomes and unexpected results. In this way, Tinkering can be viewed not only as an inquiry-based practice (Bevan et al., 2015) but also one which steps beyond the boundaries of classic inquiry in that it emphasises highly creative, open-ended design approaches in which the learner can work spontaneously and in an improvisational way.

Tinkering can be distinguished from other inquiry-based or constructivist activities by its fundamentally physical, practical, immersive and creative nature. Tinkering is a highly personal and playful process. In a Tinkering activity, the learner is presented with wide-raging tools and materials that they use to explore STEM phenomena through the process of creating something new.
When someone is engaged in Tinkering, they are not following a set of rules or seeking a known end-goal. Tinkering, as a learning process, is one in which the learner can experiment with and test design a playful and informal way through the physical act of creating or re-inventing an object of some kind. In this way, the learner is able to work towards a goal or multiple goals, which they can set for themselves according to their own interests, strengths, and motivations.

3.2 SOCIOLOGICAL CONTEXT: SCIENCE CAPITAL AND BOURDIEU

It's fooling around directly with phenomena, with tools and materials. It's thinking with your hands and learning through doing. It's slowing down and getting curious about the mechanics and mysteries of everyday stuff around you. It's whimsical, enjoyable, fraught with dead ends, frustrating, and, ultimately, about inquiry.

(Wilkinson & Petrich, 2014)

3.2.1 TINKERING AND EDUCATIONAL PEDAGOGY

Tinkering can be described as both a process and a mind-set that develops personal attributes and skills that all contribute to innovative ways of thinking and doing. Figure 7 summarises a set of fundamental features of Tinkering activities that were developed as part of the initial EU Tinkering project. At a very fundamental level, Tinkering activities involve making something through a generative, iterative process of improvisational design (e.g. design-test-refine-test-refine).

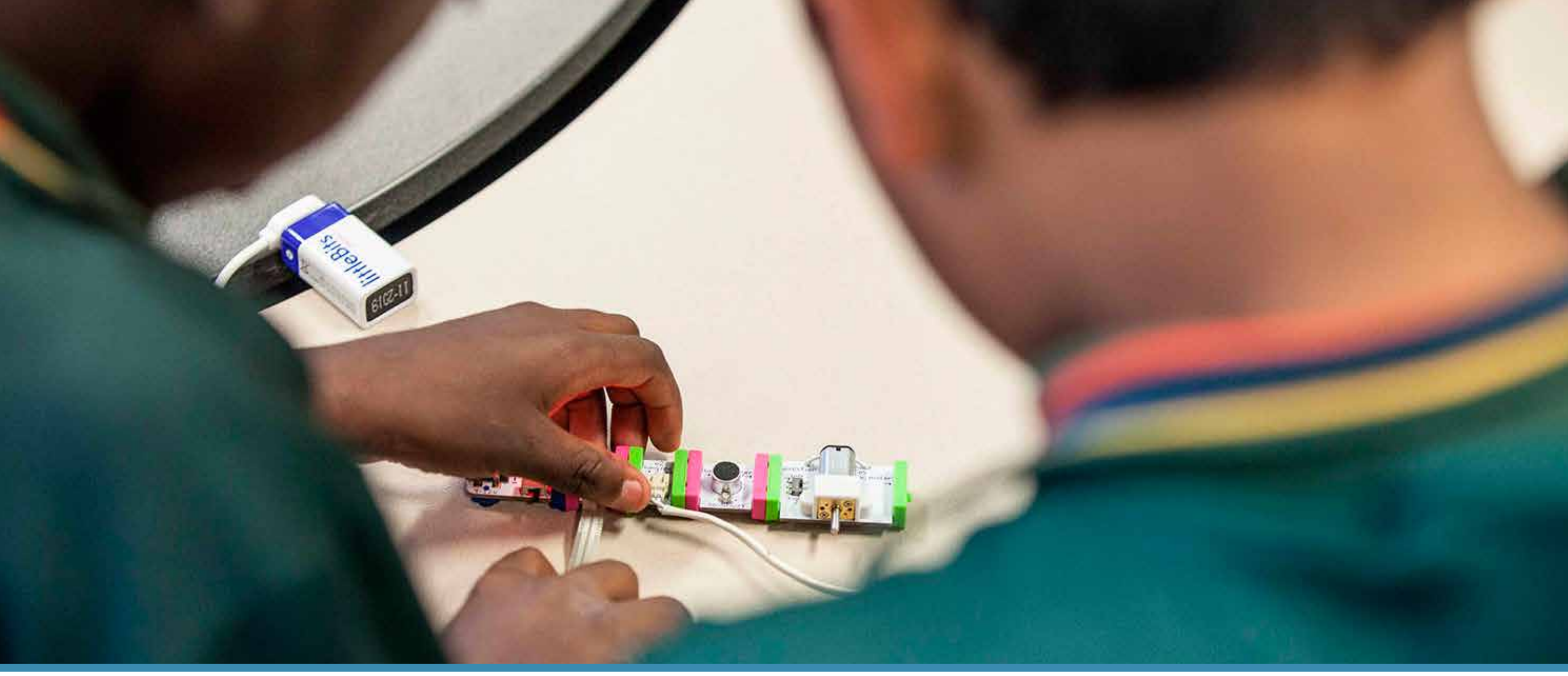
They are physical, and use a wide variety of materials and tools. In a Tinkering activity, the learner is invited to play with materials and tools - but this playfulness should not be mistaken for something trivial or without utility or purpose. Its strong personal dimension invites learners to build and become one with their own project in a 'syntonic experience' that is considered among the most powerful elements for learning. The creative nature of the experience encourages learners to pursue a new project, a new goal, a new idea, cultivating the spirit of innovation.

The sensorial and manual nature of experience supports skills that risk becoming lost in a society where digital and online platforms take precedence over physical making and crafts.

The inter-disciplinary nature of experience allows learners to use science and technology in an integrated way. Asking questions such as 'I wonder how it works' and 'I wonder what would happen if I did this' means asking the questions asked by scientists. The 'being-in/stepping back' nature of the activity invites the learner to reflect at a metacognitive level.

FIGURE 7: 10 KEY FEATURES OF TINKERING AS DEVELOPED BY THE EU FUNDED PROJECT 'TINKERING: CONTEMPORARY EDUCATION FOR INNOVATORS OF TOMORROW'
WWW.MUSEOSCIENZA.ORG/TINKERING-EU/DOWNLOAD/TINKERING-A-PRACTITIONER-GUIDE.PDF

TINKERING ACTIVITIES...	
1	Work best when you create an atmosphere of play, innovation and creativity.
2	Are sensorial and manual in nature – they enable the learner to engage in a physical, generative process of making something physical using tools and materials.
3	Are physical, immersive, creative and playful.
4	Allow people to try out technical processes, tools and/or artisan crafts.
5	Use materials that are enticing, evocative, inspiring, exciting – the materials should be inviting and spark people's curiosity and interest.
6	Give learners the freedom and opportunity to pursue their own interests and therefore to create their own learning pathways.
7	Provide opportunities for different levels of challenge and therefore allow for highly variable and often unexpected outcomes.
8	Have a long-term goal or starting point but no specific challenge or problem to solve – this allows creative ideas for new goals to emerge.
9	Are designed so that learners can negotiate their own goals, pursue and express their individual interests and engage in activities that are personally meaningful to them.
10	Provide opportunities for the learner to try something over and over and / or to work in an iterative, improvisational way - they should challenge the learner ponder, puzzle, build, test, plan, re-design, tweak and refine.



3.3 TINKERING, LEARNING AND 21ST CENTURY SKILL DEVELOPMENT

As part of its on going research into the affordances of Tinkering for learning and skill development, the Tinkering Studio team have been developing a 'Learning Dimensions Framework' which helps to describe and explain the nature of the leaning that takes place during well-planned and well-facilitated Tinkering experiences. Initially developed as part of a research project which involved video recording families taking part in Tinkering activities and subsequent coding of conversation and behaviours, the resulting framework has been developed and refined over several years. The latest version of the Learning Dimensions is shown in its current form in figure 8.

The Learning Dimension Framework helps provide an insight into the depth and breadth of learning experiences associated with Tinkering activities. When someone is tinkering, they are thinking with their hands as they ponder, puzzle, build, test, plan re-design, tweak and refine. Breakthrough moments occur when a learner becomes stuck and unstuck. The evidence of learning is apparent in the resolution of something with which they have been struggling (Bevan et al., 2015). This a very important feature of the learning in Tinkering. Tinkering requires resilience and determination, self-motivation and creative thinking. The learner engages in a process in which they set their own goals based on their own interests and motivations. They are challenged to persist in finding solutions to problems, or possibly re-forming their goals. Successful Tinkerers are creative, innovative and inventive. They are able to think divergently, to come up with new ideas and novel solutions to problems. They are brave enough to persist with an activity even though they know they might fail and are curious to learn new things and new ways of using materials and tools. They will also be collaborative, sharing ideas, listening to feedback and assimilating this into their own strategies for developing and achieving their goals. In this way, it is possible to see how Tinkering provides many opportunities to develop 21st century skills.

A summary of the opportunities that Tinkering affords for developing 21st century skills was developed as part of the first EU Tinkering project and is summarised in figure 9.

FIGURE 8 / THE TINKERING STUDIO'S LEARNING DIMENSION OF TINKERING, FROM: TINKERING.EXPLORATORIUM.EDU/LEARNING-DIMENSIONS-MAKING-AND-TINKERING

LEARNING DIMENSIONS of Making & Tinkering

Students gain valuable learning experiences while making and tinkering. Use this framework to notice, support, document, and design assessments for student learning – and to reflect on how your tinkering environment, activities, and facilitation may have supported or impeded such outcomes.

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

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FIGURE 9 / TINKERING OPPORTUNITIES FOR DEVELOPING 21ST CENTURY SKILLS ADAPTED FROM P21 DEFINITIONS FRAMEWORK (PARTNERSHIP FOR 21ST CENTURY LEARNING, 2015) AS PART OF "TINKERING: CONTEMPORARY EDUCATION FOR INNOVATORS OF TOMORROW" PROJECT

21ST CENTURY SKILLS	OPPORTUNITIES THAT TINKERING EXPERIENCES PROVIDE FOR DEVELOPING THESE SKILLS
CREATIVITY AND DIVERGENT THINKING	• Using a wide range of idea creation techniques e.g. planning, sketching, brainstorming. • Developing unique strategies, tools, objects or outcomes. • Creating new ways to use materials or tools. • Setting personal long and short-term goals and planning ways to achieve these.
INGENUITY, INVENTIVENESS AND INNOVATIVENESS	• Using or modifying others' ideas or strategies to create something new. • Demonstrating originality and inventiveness. • Understanding and experiencing real world limits to new ideas and goals. • Coming up with novel solutions and possibilities when faced with problems or obstacles.
COMMUNICATION AND COLLABORATION	• Incorporating input and feedback from other people (e.g. peers or a facilitator) into their work. • Developing, implementing and communicating new ideas to others effectively. • Being open and responsive to new and diverse ideas.
PROBLEM SOLVING, CRITICAL THINKING AND STRATEGIC THINKING	• Posing problems to solve. • Identifying emerging problems. • Coming up with solutions or methods to try to find solutions. • Elaborating, refining, analysing, testing and evaluating ideas. • Planning steps for future action.
PARTICIPATION IN OUT-OF-SCHOOL SCIENCE LEARNING CONCEPTS	• Persisting to optimise strategies or solutions. • Viewing failure as an opportunity to learn – getting stuck and working to become unstuck. • Trying something new or never (personally) attempted before. • Trying something where there is a lack of confidence in outcome. • Becoming comfortable with a process of small successes and frequent mistakes. • Persisting toward a goal in the face of setbacks or frustration.
LIFELONG LEARNING	• Striving to understand e.g. exploring confusion and/or obstacles to build new understanding. • Connecting to prior knowledge, including STEM concepts. • Employing what has been learned during explorations. • Complexifying thinking and understanding by engaging in increasingly complicated and sophisticated work.

3.4 TINKERING AND EDUCATIONAL PEDAGOGY

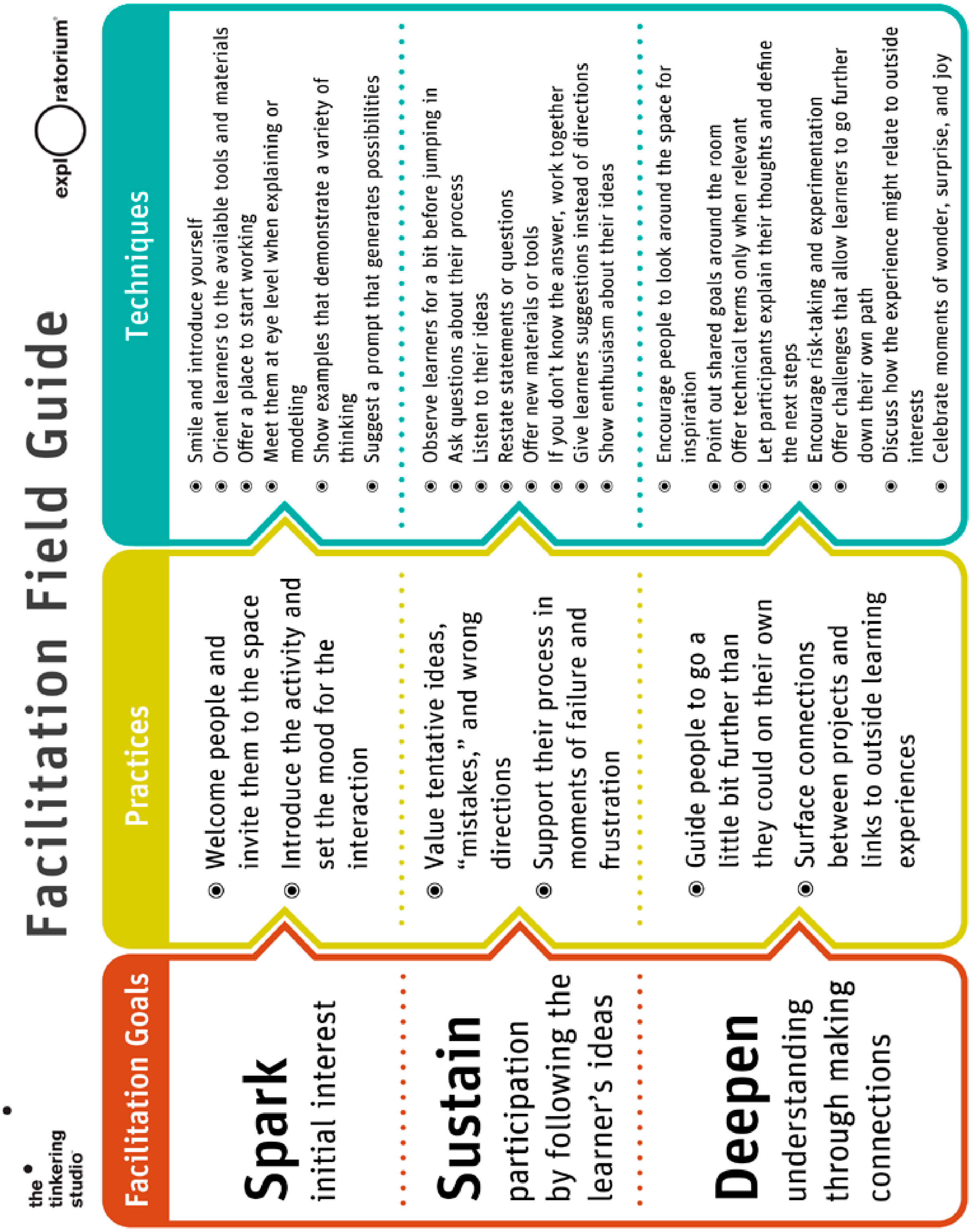
The first EU-funded project "Tinkering: Contemporary Education for the Innovators of Tomorrow" focussed on the diverse learning opportunities that Tinkering offers, particularly in relation to 21st century skills, as summarised in section 3.2. An emerging finding from this initial project was about the broad-appeal of Tinkering activities for adult learners as well students. Project partners found that a Tinkering activity developed for one particular audience (adult learners or schools) could be adapted to engage a different audience.
This is because, at a very fundamental level, a well-designed Tinkering activity is highly inclusive and can appeal to people of different ages, experiences, abilities and backgrounds. The design and the facilitation of Tinkering (see Figure 10 for a guide to Tinkering facilitation by the Exploratorium) encourages the learner to pursue his or her own goals and interests as part of a highly personal learning experience: the learner starts from their existing level of skill, knowledge or interest and builds their project or learning pathway from there. Because of this, Tinkering as a pedagogical approach relates and connects with science capital pedagogy.

Tinkering deeply values the learner's existing 'resources' (their interests, life experiences and ways of thinking) precisely because these are placed at the centre of the activity design. In a well-designed Tinkering activity, there is an overarching goal, a 'hook', to get the person started and motivated to get stuck in, but the activity should allow for smaller, personal goals to emerge from the individual's interest as they become more deeply and personally engaged in the activity.

Tinkering helps learners to engage with science and technology in an integrated and inter-disciplinary way but without formalising theories, formula or phenomena, which assume an existing level of science capital in terms of scientific literacy.
Tinkering also allows the learner to use and develop scientific thinking and practice science skills in an open-ended way. There is no right or wrong 'answer' to a problem but rather a series of negotiations for moving around a personal problem space.
The Tinkering environment is fundamentally learner-centred. An individual Tinkering activity will have very different meaning and outputs for each individual taking part in it because they have the freedom to pursue a learning path that they have chosen within the broad limits of the materials and tools they have been given.

The inclusive nature of Tinkering and how it connects with science capital – both in terms of how it directly relates to the science capital dimensions as well as its broader synergies with the Science Capital Teaching Approach, are discussed in section 4.

FIGURE 10 / THE TINKERING STUDIO'S FACILITATION FIELD GUIDE, FROM
HTTPS://TINKERING.EXPLORATORIUM.EDU/SITES/DEFAULT/FILES/SITES/DEFAULT/FILES/PDFUPLOADS/FACILITATION_FIELD_GUIDE.PDF



the tinkering studio

Facilitation Field Guide

exploratorium

Facilitation Goals	Practices	Techniques
Spark initial interest	Welcome people and invite them to the space Introduce the activity and set the mood for the interaction	Smile and introduce yourself Orient learners to the available tools and materials Offer a place to start working Meet them at eye level when explaining or modeling Show examples that demonstrate a variety of thinking Suggest a prompt that generates possibilities
Sustain participation by following the learner's ideas	Value tentative ideas, "mistakes," and wrong directions Support their process in moments of failure and frustration	Observe learners for a bit before jumping in Ask questions about their process Listen to their ideas Restate statements or questions Offer new materials or tools If you don't know the answer, work together Give learners suggestions instead of directions Show enthusiasm about their ideas
Deepen understanding through making connections	Guide people to go a little bit further than they could on their own Surface connections between projects and links to outside learning experiences	Encourage people to look around the space for inspiration Point out shared goals around the room Offer technical terms only when relevant Let participants explain their thoughts and define the next steps Encourage risk-taking and experimentation Offer challenges that allow learners to go further down their own path Discuss how the experience might relate to outside interests Celebrate moments of wonder, surprise, and joy

4

JOINING IT UP: TINKERING AND BUILDING SCIENCE CAPITAL FOR ALL

4.1 INFLUENCING THE FIELD TO HELP BUILD SCIENCE CAPITAL

So far we have discussed how science capital provides a theoretical framework for understanding patterns of participation in STEM school education and out of school STEM learning experiences as well as differences in individual STEM aspiration and STEM identity. By examining science capital, education practitioners are better able to identify where the inequality lies, why this inequality is often perpetuated though traditional STEM learning approaches and how is might be overcome. We have also seen how Tinkering as an educational approach can be used to increase STEM engagement and learning across different types of audience, particularly because Tinkering experiences are highly personal, have open-ended outcomes and are driven by the interests and motivations of the learner.

This concluding section aims to highlight and explore the synergies between Tinkering and science capital in more depth. It discusses how Tinkering can:

1 / help to build the dimensions of science capital for young people through participating in Tinkering, particularly those identified as having relatively low levels of science capital;

2 / serve to influence teaching and learning to increase equity in STEM learning.

The "Tinkering EU: Building Science Capital for ALL" project recognises that higher levels of science capital do confer advantage and that we should be aiming to build students' science capital where possible. It also understands that in order to support those at the lower end of the science capital spectrum, we need to work with the capital that those students possess in the here and now.

To help achieve its aims, project partners implement Tinkering with young people identified as facing disadvantage (which means that are likely to have lower science capital) while also supporting educational practitioners to understand the benefits of Tinkering for creating more equitable learning environments, and improving learning in their own classroom. This is because research suggests that small-scale interventions are not enough to confer significant, measurable changes in science capital.
Overcoming barriers for STEM opportunity for students with lower science capital will only be achieved by creating a more equitable STEM learning environments, including classrooms, that take into account differing levels of science capital and which utilises the resources that young people do have.

The project is based on a resilience rather than a deficit model for overcoming inequalities in STEM participation: it is not that the young people with low science capital have something fundamentally wrong that needs to be improved, it is rather that the context in which they are learning needs to change in order to better utilise and build on students' existing resources in order to help them feel valued, empowered and better able to identify with STEM both in and out of school.

The main aims are:

- to improve the science skills of young people, especially those from disadvantaged groups.
- to help young people develop 21st century skills, particularly creativity, innovation, entrepreneurship and critical thinking.
- to improve school practice through innovative Tinkering pedagogy underpinned by science capital research and practice.
- to promote student-centred learning.
- to support the work of teachers.
- to encourage exchange of expertise and practice between formal and informal learning institutions.
- to create a European community of practice, bringing concrete improvements to several countries and maximising the dissemination of Tinkering and Science Capital pedagogy across Europe.
- to build on exchange of expertise across high quality institutions, working under a common goal and acting upon similar needs.
- to contribute to the implementation of the EU strategy and policy for education and training.

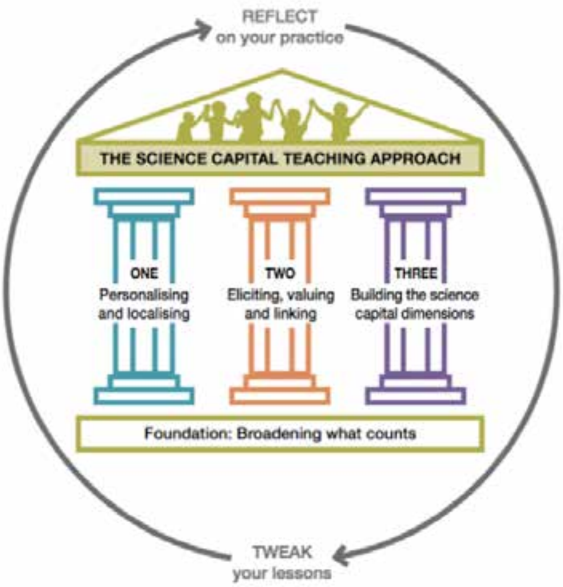
4.3 TINKERING AS PART OF A SCIENCE CAPITAL TEACHING APPROACH

Section 2.3 introduced the newly developed Science Capital Teaching approach. At a very basic level, this approach asks educational practitioners to explore and understand all of the wider experiences that influence a young person's science identity and STEM aspirations (the dimensions of science capital), in order to curate learning experiences that value a broader range of lived experiences and which help young people to understand how their lives can and do relate to STEM in a personally meaningful way.

In section 3, we went on to explore the benefits of Tinkering for developing a broad-range of learning dimensions including scientific literacy and 21st century skills, particularly in the areas of creativity, problem solving, resilience, and collaboration.

But how exactly might Tinkering support a social justice agenda and align with science capital pedagogical practice?
Where do these two emerging educational approaches connect?

Below we use the three pillars model (introduced in section 2.3.2 and presented again below) to highlight the ways in which Tinkering relates most directly to the science capital dimensions and to the Science Capital Teaching Approach.



4.2.1 TINKERING AS TOOL TO 'BROADEN WHAT COUNTS'

At its foundation, the Science Capital Teaching Approach is underpinned by an understanding of the importance of the educational environment in which students learn. It encourages practitioners to develop and maintain a STEM teaching mind-set that recognises a broad range of experiences, skills and behaviours as having a legitimate place in the science classroom (Godec et al., 2017). 'Broadening what counts' is about creating a supportive, welcoming, inclusive environment in which all students feel that they can offer contributions from their own lived experiences and that these are valid and will be valued.

At a very basic level, Tinkering can be a useful tool for STEM practitioners to 'broaden what counts as science' in their practice. Tinkering is not about providing the learner with scientific facts and information from the outset (although STEM facts, skills, processes and theories may be learned as part of doing Tinkering, as will be discussed in 4.2.4), but rather it is about drawing them in using tools and materials that are enticing and which create opportunities for the learner to express their interests by choosing and pursuing their own goals. The environment in which Tinkering takes place is one that is welcoming, supportive and which values ideas and individual contributions, including personal responses.

A good Tinkering facilitator will share and celebrate moments of wonder as well as interesting thoughts and experiences that learners have. By using Tinkering in the STEM curriculum, practitioners can draw students' attention to personal attributes such as curiosity and resilience, and skills such as questioning and testing ideas valued in STEM, and emphasise that science is not just about learning science facts or getting the 'right' answer.
Indeed, the playful, creative nature of Tinkering and its focus on iterative design (design, make, test, tweak, refine, re-design) encourages an understanding of the experimental nature of STEM, and of learning through mistakes and unexpected outcomes.

4.2.2 PILLAR 1 PERSONALISING AND LOCALISING

In the Science capital Teaching Approach, 'personalising and localising' is about helping students to see that their interests, attitudes and experiences outside of school do relate to STEM. It encourages practitioners to build STEM learning experiences from students' existing interests and ideas and to link learning to students' local lives and communities. By using personal contexts, the content of lessons can speak more directly to the immediate 'here and now' of students' everyday lives therefore helping students who may not perceive themselves as 'sciencey' to relate to STEM.

This idea of 'personalised and localised' learning is at the very heart of a well-designed Tinkering experience. As already touched upon in section 3.3, Tinkering is a highly inclusive experience which aims to spark interest by allowing the learner to set their own goals and follow their interests, resulting in a personal project which is individually meaningful and builds from the learner's existing knowledge and ideas. We also discussed in section 3 how Tinkering can be described as both a process and a mind-set and that the process embodies all sorts of skills and dispositions. By allowing students to explore a STEM problem space in a very open-ended way, the learner is able to experience STEM in ways that can link more directly to their own lived experiences. For the science teacher, Tinkering can provide opportunities to create personalised learning experiences for students that draw upon individual interests outside of school or current career aspirations. The facilitation of Tinkering also supports this process of 'personalising and localising' because it attempts to help the learner to build connections between their Tinkering experience and outside interests.

4.2.3
PILLAR 2
ELICITING VALUING AND LINKING

STEM teaching that 'elicits, values and links' is focussed on making sure students know that their interests, ideas, knowledge, experiences and cultural background are valid within the context of STEM. This can help students to feel more engaged and empowered to contribute in lessons. By using open questioning techniques, teachers can try to elicit knowledge that comes from the context of students' home and community life outside school. By following-up on comments and linking these to STEM learning contexts, teachers demonstrate that these experiences are valued and valid.
This element of the Science Capital Teaching Approach also acknowledges the importance of including all students in lessons, especially those who might be quiet or shy. This might be done, for example, by using small group or paired discussion before asking students to contribute to larger group discussions.

Tinkering has many features in common with this element of science capital pedagogy. The Tinkering environment (everything making up the Tinkering activity including materials and facilitation) provides a safe, non-judgemental space and an opportunity for learners to express themselves and their ideas with complete freedom of expression.
The Tinkering environment is a 'flat space' where teachers aim to facilitate or even collaborate with learners, rather than direct the learning journey. Facilitation is structured around open questions (see figure 10); it also celebrates and values what the learner is feeling, experiencing and trying out, rather than focussing on 'correct' or pre-determined outcomes. As previously discussed, Tinkering activities deeply value personal experience.
They allow the learner to pursue individual interests and engage in activities that are meaningful to the individual as they negotiate their own goals and create their own learning pathways. Related to this is the fact that Tinkering does not require or assume any formalised STEM theory or technical scientific terminology. This means that language barriers are reduced and students can engage actively and meaningfully, even if they have lower levels of existing science, or are facing language-related disadvantage. This means that language barriers are reduced and students can engage actively and meaningfully even if they have lower levels of existing science- or language-related. Tinkering can be a hook for talking about or illustrating scientific processes, facts, formulae and theories, but this is not the starting point, nor the intended outcome, and so students who may not feel that 'science is for me' are less at risk of feeling alienated and may feel more empowered to take part.

4.2.4
PILLAR 3
BUILDING THE SCIENCE CAPITAL DIMENSIONS

Until now we have been discussing the ways in which Tinkering can help shape the field around the learner, create a more equitable landscape in which a wider variety of dispositions, skills, experiences and ideas are valued and legitimised in the STEM learning space. Tinkering does also relate directly to the individual dimensions of science capital outlined in section 2.

For example:

- In the project, students with relatively low levels of science capital will experience Tinkering in out of school contexts. This is something that these students are less likely to be doing regularly in their lives outside of school. This could help to build dimension 5.

- Tinkering can encourage learners to talk about science in their everyday lives and discuss the experience with friends and family. This is even more likely if students find the experience genuinely engaging, interesting and relevant to their everyday lives. This could help to build dimension 8.

- Although this is not an integral part of Tinkering activity design, Tinkering activities often implicitly demonstrate the utility and transferable nature of STEM skills because Tinkering activities draw upon and work across different media, methods and disciplines. This could help to build dimension 3.

- There are also many possible scientific literacy gains for learners taking part in Tinkering. It is important for teachers to understand that scientific literacy gain will vary depending on the type of activity and the extent to which scientific content and STEM skills being developed are made explicit through the facilitation and post-activity plenary work. For example, the Tinkering Dimension 'Conceptual Understanding' (Figure 8) summarises some of the possible scientific literacy gains that Tinkering can afford. This could help to build dimension 1.

FORWARD

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NOTES

[1] The UK ESRC-funded ASPIRES study (2009-2013) tracked the development of young people's science and career aspirations from age 10-14. ASPIRES 2 is continuing to track young people until age 19.

[2] Enterprising science (2013-2017) further developed the concept of science capital and was targeted at exploring science attitudes and engagement with a greater focus on how science capital might be formed or built.

[3] Introduction to 'Science Capital Teaching Approach' at the Enterprising Science Teacher Conference at the National STEM Learning Centre, York, Friday 13 October 2017.

[3] Science Capital Teaching Approach Professional Development Event, London City Hall, Saturday 17 March 2018.