SENSE. The New European Roadmap to STEAM Education

D3.5 – SENSE.STEAM Methodology

August, 2023

Funded by the European Union

Project information

Project acronym:	SENSE.
Full title:	The New European Roadmap to STEAM Education
Grant agreement:	101058507
Programme and call:	Horizon Europe, HORIZON-WIDERA-2021-ERA-01
Project coordinator:	Lydia Schulze Heuling, Western Norway University of Applied Sciences
Contact:	HVL-SENSE@hvl.no
Project duration:	36 months (1 September 2022 - 31 August 2025)
Project website:	www.sense-steam.eu

Deliverable information

Deliverable number	D3.5
Deliverable title:	SENSE.STEAM Methodology
Dissemination level:	PU
Deliverable type:	Report
License:	CC BY-NC-SA 4.0
Status:	Submitted
Due date:	31/08/2023
Submission date:	31/08/2023
Work Package:	WP3
Lead Beneficiary:	CREDA onlus

Disclaimer

Copyright information

Revision History

Date	Version	Author	Comment
01/01/2023	v0.01	Lydia Schulze Heuling	Creation of ToC
01/01/2023	v0.02	Lydia Schulze Heuling	First draft of content
16/02/2023	v0.03	Sasha Brown	Structure to provide collective writing
24/02/2023	v0.04	Lydia Schulze Heuling	First draft with contribution from all partners
09/05/2023	v.0.05	Sasha Brown	Alignment of formatting
07/07/2023	v0.06	Laura Colucci-Gray	Editing
02/08/2023	v0.07	Lydia Schulze Heuling	Editing for final draft
25/08/2023	v0.08	Anne Krebs and Lydia Schulze Heuling	Review and approval
31/08/2023	V1.0	Nickolai Birkland, HVL	Final check and submission to the granting authority

Author List

Institution	First name and Name	Contact information
HVL	Lydia Schulze Heuling Sasha Brown Laura Colucci Gray Idar Mestad	lshe@hvl.no sasha.brown@hvl.no laura.colucci-gray@ed.ac.uk idar.mestad@hvl.no

Louvre	Anne Krebs Inès Moreno Lopez	anne.krebs@louvre.fr ines.moreno@ehess.fr
H\B	Michael Riebel	MichaelRiebel@hawkinsbrown.com
PHW	Florian Theilmann David Bockstahler	theilmann@ph-weingarten.de david.bockstahler@ph-weingarten.de
UB	Josep Perelló	Josep.perello@ub.edu
Odyssea	Theodoris Kostoulas	theodoris.kostoulas@odsea.com
WECF	Anna Samwel Ana Muradashvili	anna.samwel@wecf.org ana.muradashvili@wecf.org
GEYC	Adelina Dragomir	Adelina.dragomir@geyc.org
CREDA onlus	Daniela Conti Carolina Bianchi	daniela.conti@creda.it carolina.bianchi@creda.it
Velvet	Joseph Sturm	joseph@velvet.ee

Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
AR	Augmented Reality
CS	Citizen Science
CSS	Citizen Social Science
DoA	Description of Action
EOC	Educational Outside-the-Classroom
EU	European Union
IBSE	Inquiry Based Science Education
ICT	Information and Communication Technologies
PIC	Profile – Investigate - Create
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
NRC	National Research Council

Glossary

Term	Definition used or meaning in the SENSE. project	Reference or source for the definition if applicable
Activity	An activity in education is a distinct and specific task or action undertaken as part of a larger educational practice.	D3.4
Art Practice/Art Intervention	A creative and sensory process encompassing research, exploration, translation, or production. An artistic practice can also be an artistic intervention if it transcends conventional artistic boundaries and deliberately engages with contexts, issues or spaces with the aim of catalysing meaningful impact or provoking critical discourse.	D3.2
Artistic research	Artistic research involves the creative exploration of artistic or aesthetic practices. Artistic inquiry is a dynamically evolving field that embraces diverse perspectives and multiple epistemologies.	D3.2 and D3.5
Citizen Science	The term is commonly used to describe different forms of participation in scientific knowledge production and even to describe various forms of participatory action research and digital volunteerism.	Haklay et al. (2021)

Citizen Social Science	Citizen Social Science combines equal collaboration between citizen groups (co-researchers) that are sharing a social concern and academic researchers. Such an approach enables to address pressing social issues from the bottom up, embedded in their social contexts, with robust research methods.	CoAct project webpage
Embodiment	Forms of knowledge which are acquired through somatic experience and interaction with the environment.	D3.4, D3.5
Enquiry	In contrast to scientific inquiry, enquiry emphasizes a holistic, exploratory approach that explicitly embraces detour, uncertainty and curiosity.	D3.5
Inquiry, scientific	Scientific inquiry involves the gathering of information, systematic investigation and the examination of facts or principles.	Merriam Webster
Learning Companion	A supportive and interactive educational companion, designed to assist learners in their educational journey by providing guidance, resources and personalised feedback. It aims to enhance the learning experience and	D3.4

	help individuals achieve their educational goals through adaptive and tailored approaches.	
Meta-disciplinarity	The term "meta" means to overcome and to preserve. Approach that considers that every discipline is, at the same time, both open and closed.	Morin (1999)
Practice	A STEAM practice in education refers to a comprehensive and systematic approach that includes activities and strategies based on principles used to achieve STEAM educational impact.	D3.4
Research creation	Research creation refers to the integrated process of artistic exploration and scholarly inquiry in which creative practice and scholarly inquiry inform and enrich each other to produce innovative insights and works.	D3.5
Reverse Ontology	Teaching logic that progresses from abstract models to procedural applications.	D3.4, D3.5
SENSE. Manifesto	A living document that succinctly articulates the partners' shared principles, values and goals, serving as a guiding framework that unifies members' efforts and communicates their distinctive perspective or	D3.4

	transformative vision to a broader audience. This manifesto provides a clear direction that fosters cohesion and resonance within the collective, while signalling its distinctive contribution to STEAM to the larger discourse.	
STEAM beneficiary	STEAM beneficiaries are individuals or organisations who directly gain advantages from a STEAM-focused initiative as SENSE. They experience direct improvements in learning, skill development or well-being. For instance, students participating in a STEAM education program are beneficiaries as they directly benefit from the enhanced learning experiences and opportunities for creativity and critical thinking.	D3.3
STEAM Stakeholder	STEAM stakeholders encompass a broader range of entities such as students, companies or policy makers. Each of these groups has distinct interests and roles in the success of a STEAM initiative. For example, educators contribute to the design and delivery of STEAM curricula, while policymakers influence funding and educational	D3.3

	policies related to STEAM education.	
Transdisciplinarity	Approach to the world, cognitive schemes that go beyond the disciplines, grasping the complexity of the world.	Morin (1999)

The SENSE. project

There is a widespread understanding that the future of a prosperous and sustainable Europe depends to a large extent on the quality of science education of its citizens. A science-literate society and a skilled workforce are essential for successfully tackling global environmental challenges, making informed use of digital technologies, counteracting disinformation, and critically debunking fake news campaigns. A future-proof Europe needs more young people to take up careers in science related sectors.

Research shows that interest in STEM subjects declines with increasing age. This effect is particularly pronounced among girls and young women; even those of them who take up science studies gradually forfeit their motivation. But despite all image campaigns and efforts to remove the awe of science only “one in five young people graduates from STEM in tertiary education” and only half as many women as men, according to the European Skills Agenda.

The disinterest in science is striking and evokes the question of its causes. Stereotypes and lack of female role models seem to be only a part of the explanation. Nor is there a lack of career prospects that could explain a reorientation despite initial interest.

SENSE. has identified two major problems in current science education that need to be addressed: a) A distorted teaching logic that progresses from abstract models to procedural applications (“reverse ontology”) and b) The inability to implement a learner-centred pedagogy linking students’ everyday knowledge to science-based knowledge, thus promoting motivation, self-directed and life-long learning.

SENSE. advocates for the development of a high-quality future-making education that is equally accessible to all learners and promotes socially conscious and scientifically literate citizens and professionals. SENSE. aims at radically reshaping science education for a future-making society. By promoting the integration of all human senses into exploring and making sense of the world around us we will challenge conventional ideas of science and science education. Considering the pitfalls of current science education practices and the advantages of artistic and aesthetic activity, this innovative approach also considers social inclusion and spatial design as core components for a new STEAM education paradigm. With ‘SENSE.STEAM’ future science learning will be moving away from the standardised classroom shapes and furniture layout entering new learning landscapes.

The project seeks to develop an accessible educational roadmap promoting socially conscious and scientifically literate citizens and professionals. It addresses outdated perceptions of current science education as well as gender stereotypes by integrating the arts, social inclusion and spatial design as its core components. SENSE. will establish 13 ‘STEAM Labs’ across Europe to develop and evaluate the

‘SENSE. approach’ to STEAM subjects alongside students, educators, teachers, businesses and other stakeholders.

The ‘New European Roadmap to STEAM Education’ will take the shape of a STEAM learning companion to support tomorrow’s educators and learners – be it in the classroom, in a museum or on a drilling rig. A digital hub will be established, where practitioners from all ages and backgrounds across Europe will be able to access tried and tested educational practices to increase engagement within these subjects.

The SENSE. consortium

Høgskulen på Vestlandet	Inndalsveien 28 P.O Box 7030 5020 Bergen, Norway	https://www.hvl.no/en/
odyssea	Karditsis 8A Athina 104 40, Greece	www.odyssea.org.gr
Pädagogische Hochschule Weingarten	Kirchplatz 2, 88250 Weingarten, Germany	www.ph-weingarten.de
CREDA ONLUS	Via Mulini Asciutti 2, Parco Monza 20900, Monza, Italy	www.creda.it
wecf	Kote Elisabethstraat 6, Utrecht 3511 JG, Netherlands	www.wecf.org
geyc	Strada SF Elefterie 31 Corp a et 2 AP 3, Bucuresti 050524, Romania	http://www.geyc.ro
LOUVRE	Quai Francois Mitterand 34/36, Paris 75001, France,	www.louvre.fr
Hawkins\Brown	22 Elyplace, Dublin D02 AH73, Ireland	www.hawkinsbrown.com

VELVET	Telliskivi 60a/5, Tallinn 10412, Estonia	www.velvet.ee
UNIVERSITAT DE BARCELONA	Gran Via De Les Corts Catalanes 585, Barcelona 08007, Spain	www.ub.edu
EFEE THE EUROPEAN FEDERATION OF EDUCATION EMPLOYERS	Rue Des Deux Eglises 26, Bruxelles 1000, Belgium	www.educationemployers.eu

The SENSE. Associated Partners

VILVITE	Thormøhlensgate 51 5006 Bergen, Norway	www.vilvite.no
TRELLEBORG	Johan Kocksgatan 10 P.O. Box 153 231 22 Skåne län, Trelleborg, Sweden	www.trelleborg.com
FUNDACIÓ BOFILL Educació per canviar-ho tot	C/Provença 324 08037, Barcelona, Spain	www.fbofill.cat
S·H·E	Irisvej 36 Anette Schulz P.O. Box 000 7100, Velje, Denmark	http://www.schools-for-health.eu/she-network
Primăria Municipiului Câmpina	Bulevardul Culturii Nr 18 105600 Sud - Muntenia, Campina, Romania	www.primariacampina.ro

THE UNIVERSITY of EDINBURGH	Old College, South Bridge EH8 9YL, Edinburgh, United Kingdom	www.ed.ac.uk

Executive Summary

This executive summary captures the essence of the SENSE.STEAM methodology, an innovative and holistic approach to education that forms the cornerstone of a comprehensive and change-driving learning experience for individuals and society at large. The methodology is instrumental in creating a value chain that empowers learners and enhances societal impact. The document includes the core principles of SENSE.STEAM, its pedagogical components and strategic pathways and outlines a roadmap for the future of STEAM education in Europe and beyond.

The SENSE.STEAM methodology is a beacon of guidance in the pursuit of a more inclusive, impactful and effective educational paradigm. This summary culminates in a reflection on the meticulous interweaving of insights, methodologies and considerations that provide the theoretical foundation for the end goal: the New European Roadmap for STEAM Education.

Section 2 of the document presents a comprehensive evolution of STEAM education that goes beyond the mere fusion of disciplines. It emphasises the transformative nature of STEAM, where artistic creativity merges with scientific inquiry to foster imagination, empowerment and innovation in STEM and STEAM fields. The literature review highlights the importance of harmonising artistic infusion and scientific exploration for holistic learning experiences.

STEAM education is not limited to the transmission of knowledge, but is the channel for learning from past experiences, successes and failures. It empowers learners to imagine and create their future world. Recognising the limitations of traditional approaches in STEM and STEAM education, SENSE.STEAM advocates a diverse range of perspectives to cultivate empowerment and transformation of future generations.

At the heart of the SENSE.STEAM approach are key components that move education into learner-centred, reflective and collaborative realms – see section 3. By reinvigorating the interaction between art and science through STEAM inquiry, learners are given the tools to explore uncharted territories of knowledge and map multiple epistemologies. Encouraging public engagement with science and the arts democratises learning and provides a platform for community engagement and societal progress.

Embedded in the methodology are core pathways that address critical challenges and unlock untapped potential. Environment and space, social inclusion, gender equality, and the societal value of arts and culture are key pathways that underscore SENSE.STEAM's comprehensive approach. Embracing these pathways fosters an inclusive educational ecosystem that thrives on diversity and collaboration.

This document goes beyond theoretical discourse to guide action and advocacy for STEAM education. It identifies strategic entry points for integrating SENSE.STEAM into policy and practice, building bridges to a future where STEAM education is

universally accessible. By leveraging international documents, partnering with existing initiatives, and aligning with national curricula, SENSE.STEAM paves the way for a future-making learning continuum.

The SENSE.STEAM methodology, its educational components, pathways and entry points serve as foundational elements of a more inclusive, innovative European educational landscape. May this document serve as a guiding compass to steer us towards an educational journey where learners are empowered to shape their destiny and society thrives as a result.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Purpose of the document

This document outlines the SENSE.STEAM methodology and the various components involved in delivering a comprehensive and effective education, forming a value chain for learners and society. It includes a reflective summary on the art of STEAM education, a presentation of the educational key components and core embedded pathways of a SENSE. approach to STEAM education, and an identification of programmatic entry points for SENSE.STEAM in policy and practice in Europe and beyond. This document will form the theoretical point of reference for shaping the New European Roadmap to STEAM Education, the final result of this project.

1.2. Intended readership

This comprehensive document is addressed to the full spectrum of stakeholders and beneficiaries, as meticulously outlined in Deliverable 3.3. In the pages that follow, we unveil the foundational model that underpins SENSE. and illuminate its position within the context of current research and ongoing initiatives. Through an exploration of its alignment with STEAM education, we delineate the components that form the basis of SENSE.'s value chain, making this document a comprehensive and rich resource for every reader.

1.3. Structure of the document

Laying out the SENSE. approach to STEAM, this document begins with a reflective summary on the art of STEAM education (section 2), a presentation of the educational key components and core embedded pathways of a SENSE. approach to STEAM education (section 3) followed by an identification of programmatic entry points for SENSE.STEAM in policy and practice in Europe and beyond (section 4).

1.4. Relationship with other deliverables

This document builds upon the previous deliverables in Work Package 3 for the establishment of the project's methodology (D3.1 Report on the STEAM DNA Workshop, D3.2 Report on the Citizen Science and Art-Practices Workshop, D3.3 Report on Stakeholder Challenges and Needs for future-making STEAM Education in Europe and D3.4 Report on knowledge and practices for a New European STEAM education).

The SENSE.STEAM methodology will form the basis of the work of WP4 (Steam Labs), WP5 (Cross-cutting issue: space), WP6 (Cross-cutting issue: social inclusion) and will be incorporated into the Roadmap in WP7 (Consolidation of the STEAM Roadmap and its supporting tools).

2. STEAM education – state of the art

Over the last 15 years, the EU has made large investments into STEM and STEAM educational projects seeking to encourage inquiry-based (e.g., SAIL, MASCIL, CreativeLittleScient) and art-based approaches (e.g., DesignEng, iMuSciCA, eCraft2Learn, TheatreInMath) as a means for developing new scientific skillsets (e.g., Steam+) alongside broader competences for democratic participation in issues of science and society. Recent contributions from the science education literature are arguing for a new vision in science education, one that recognises that there are a number of issues that need to be addressed (Dillon and Watts, 2023).

In one instance, across Europe, the career pathways of school students, particularly girls and young women, remain virtually unchanged [ScienceEurope, 2023). While children at the primary school level are fascinated by science and maths, most of them lose their interest in STEM during their teenage years and are less likely to engage in science careers [Michaelides et al., 2019]. This trend leads to a second problem concerning the ability of European economic and social systems to provide life-chances for students to develop their talents and ultimately, strengthen Europe's R&I capacity to address societal and environmental challenges (Trotman, 2017).

SENSE. has identified two main areas in current science education that need to be addressed: a) A distorted teaching logic that progresses from abstract models to procedural applications ("reverse ontology") (Dahlin, 2003; Østergaard, 2017) and b) The inability to implement a learner-centred pedagogy linking students' everyday knowledge to science-based knowledge, thus promoting motivation, self-directed and life-long learning (Hagendijk *et al.*, 2020). Instead of being fascinated by scientific inquiry, students are feeling excluded and alienated from STEM subjects (Roth, 2015) because what they are taught in science class is scarcely (if ever) put in relation to their personal lives; students' own experiences and knowledge are not reflected in the science that is presented in schools and textbooks, and finally, the primary emphasis of science teaching is on cognition, thus diminishing the value of students' sensory experiences, creativity, emotions, values and attitudes towards education more generally, and STEM subjects specifically (Schulze Heuling, 2021).

Such debates underpin recent arguments on the need to re-think the science curriculum to extend beyond the teaching of traditional academic subjects, and beyond the boundaries of the laboratory, to support creativity and engagement of pupils with 'real' science, in 'real' world settings. The process of teaching and learning would thus extend beyond the acquisition of content to include opportunities to make connections across subjects and topics, engage with creative thinking but also developing new perspectives on the processes of knowing itself, for a more diverse, equitable and sustainable science education (Burnard *et al.*, 2019).

With the ambition to produce a Roadmap for implementation across the EU, SENSE. is grounded into a consolidated methodology for stakeholders' engagement, from mapping needs to co-creation, which builds upon a renovated conception of cognition beyond abstract thinking, to include the sensing body as an extended modality of knowing across time and space. Inclusion and multiplicity of perspectives are harnessed across formal and informal contexts as a basis for wider engagement and co-creation of knowledge. The SENSE.STEAM methodology is thus designed to introduce a paradigm shift in STEAM education, by stimulating learners' self-directed and co-operative learning s and to empower all users to co-design their own STEAM curricula. In this section we will review key debates in the literature; proceed with an analysis of a spectrum of practices and illustrate the key theoretical stances and approaches to enact SENSE.STEAM in real-life contexts.

2.1. Review of the literature

In its simplest terms, STEAM is defined as STEM with the addition of the ARTS. In this view, the recent rise of STEAM education points to a need to reformulate curricula by drawing specifically on creativity, design, and innovation from the realm of the arts to enhance the impact of subjects that are seen as instrumental to developing the economy. Conversely, research involving marginalised and disadvantaged groups, including women and people of colour, particularly in the US, pointed to the potentialities of arts education to engage, positively attend school and perform well (Liao, 2016) . Hence, STEAM education is not simply a means to do STEM better to enhance social and economic mobility; but mostly a means to provide equitable opportunities for all students to participate in their own education. Defining STEAM as a transdisciplinary paradigm (Costantino, 2018, p. 100) rather than a more effective STEM paradigm makes it relevant for the teaching of all disciplines, with the end goal being the enhancement of social cohesiveness, the building of diverse relationships, as well as deeper learning and creative problem solving (Marshall, 2010). Similarly, a transdisciplinary approach is advocated on the basis of valuing epistemic diversity, that is, the inclusion and enhancement of different and diverse creativities and ways of knowing, integrating the conceptual with the practical and experiential; linking the formal curriculum with and through the local curriculum of one's community, culture and place (Schulze Heuling, 2021; Burnard, Colucci-Gray and Cooke, 2022).

In practice, many different configurations of STEAM exist, each one sharing one or more of the following structural features:

- Inclusion of disciplines which may or may not be part of traditional school curricula, such as Engineering (Brophy *et al.*, 2008), with a focus on DESIGN-BASED learning;

- Re-purposing of subjects as conventionally taught in schools by emphasizing applied and economically relevant dimensions (e.g., Design and Technology Education turning into Creative Industries; Brown et al., 2011), with a focus on READINESS FOR WORK.
- The combination of academic and vocational subjects, such as sciences and the arts in transdisciplinary creative inquiries (Colucci-Gray *et al.*, 2019), with a focus on PARTICIPATION & SUSTAINABILITY.

Critical to the different positions and their different aims is the role of the arts and the sciences and their relative contribution to the process of creation of collective knowledge. In this review we will focus on two main approaches that we situate on a spectrum: a. art-infusion which is largely aimed at maintaining the disciplinary status of STEAM and Arts subject and b. future-making, which is aimed at the creation of new knowledge by drawing on a multiplicity of approaches from the sciences and the arts.

2.2. STEAM as art-infusion

While integrated teaching takes multiple forms, discussions of STEAM education in this camp often focus on arts-integration instructional strategies and lesson ideas as constituting STEAM education. For example, the arts would allegedly bring in creativity, personalisation and motivation to the teaching of science subjects (Perignat and Katz-Buonincontro, 2019), while engineering would help contextualise and integrate students' learning (Breiner *et al.*, 2012). The anticipated benefits of STEAM - based on art fusion – would thus equate to a more successful transfer of academic content, leveraging the complementarity of numerical and communicative skills (Quigley, Herro and Jamil, 2017; Torres Gomez *et al.*, 2021).

While this approach may appeal to the necessity of improving academic performance, and indeed significant relationships between arts engagement and academic achievement have been reported (Catterall, Dumais and Hampden-Thompson, 2012), this view of STEAM is deeply rooted into instrumentalised views of education, perpetuating similarly instrumentalised views of technology and the arts. Their role is redefined to 'supporting creativity' as a skill confined to the service of some other attributes, be it a mathematical skill or a psychological attribute, as opposed to practices that enhance "students' creativity such as encouraging unique ideas, taking appropriate risks, learning from mistakes, and exploring new materials" (Perignat and Katz-Buonincontro, 2019, p. 32).

Basic assumption of Art-Infusion
In this approach to STEAM education the educational 'doings' of the arts as particular forms of knowing and learning, the experiences they may produce, as well as what they make possible for children are directed towards pre-defined goals and outcomes (Biesta, 2018). The fundamental assumption is that what is to be known can be pre-set and the teacher makes a choice about which subject may be used to best convey a particular set of content; for example, drama can be used with biology to

illustrate the relationships within a food web; a competitive game may be used in combination with ecology to show the dynamics between prey and predator. The combination of different subjects may thus serve the purpose of facilitating access to the school curriculum and increasing learning outcomes.

2.3. STEAM as future-making

This approach is grounded in the desire to promote artistic and scientific inquiry practices on equal terms (Schulze Heuling, 2017; Burnard, Colucci-Gray and Sinha, 2021). The sciences will include the broad spectrum of disciplines focussing on different scales (from micro- to macro) and harnessing different modalities for understanding reality, e.g. through time; through relations; through processes of inputs and outputs (Colucci-Gray *et al.*, 2013). Similarly, the arts will include the broader spectrum of design, computer graphics, coding, performing arts, or creative problem solving – and ranging from art forms to art-practices – engaging students with working collaboratively on real-world issues, experiences and applications that have no definitive solutions (Cook *et al.*, 2020).

In this modality, instead of promoting common conceptions of STEAM as the addition of the Arts to science-related disciplines we draw the potentiality of STEAM as a construct with the potential to dismantle hierarchical relationships between disciplinary subjects, epistemic discourses and material practices. Underpinning this approach to STEAM is a commitment to trans-disciplinarity, a stance on knowledge that recognises system complexity; the interdependences between multiple levels of the same reality (e.g., the physical, perceptive and imaginary realms) and the inseparability of subject and object (Nicolescu, 2012). This approach is rooted into a form of knowing through and via relationships that may be conceptual, affective, but also engaged in material and communication exchanges. In this sense, STEAM as future-making education brings together a diversity of people and groups into processes of co-creation of knowledge but also on the making of common, desirable futures.

Core to this thinking is the notion that knowledge is not the concern of a mind or body that are independent from context, but rather, knowledge concerns the relationship between the activities of organisms and the consequences these activities bring about. The 'environment' in which any organism operates is not defined geographically as a portion of space, but more narrowly by the particular ways in which every organism is physiologically and culturally set to be coordinated *with* (Vanderstraeten, 2002). For example, the hard shell of a mollusc is the result of the organism's ability to coordinate its actions in the turbulence of the marine environment. The organism co-construct itself by drawing in the minerals from the environment, while at the same time modifying its own internal environment (e.g., the pumping in of minerals through the cell membranes for the construction of the shell). Yet, in that process, the localised external environment also changes as a result. This implies that the world is never independent of the activities of the organism, and that knowledge is always engaged in action. Johnson (2007) refers to concepts and thoughts as 'patterns of experiential interactions', as basic and recurrent structures which emerge from the sensorimotor experience of the organism encountering the world.

Action and movement *in* the environment therefore define what enters the field of perception, what the organism pays attention to, and thus, what the organism knows. In developmental terms, such organism-environment relations are further mapped onto cognition and the development of language. For example, image-schemata such as 'close' and 'warm' derive from early experiences of physical contact with a caregiver, projected into language and metaphorical thinking. Such early experiences are fundamental to forging value-orientations and attitudes for different people; shaping what different individuals may be concerned with, interested in or distant from (Greene, 2001). It is a process that sits at the heart of individuality and difference in the ways people approach their learning and how they may lead their lives.

2.4. Basic assumption of future-making

In educational terms, STEAM as future-making emphasises that it is not just knowledge - disciplinary or multi-disciplinary, but it is the question of attention that is central to education. If the aim of science education is that of preparing for life in a changing world, as opposed to shaping attention towards outcomes already known in advance, then the question of pedagogy becomes *what kind* of attention is needed. In this view, SENSE as future-making, emphasises the potentiality of the sensing body as the prime locus of cognition, bringing together abstract conceptualisations, that are static and bounded with aesthetic thinking, that is dynamic and contingent. This capacity engages the full range of sensorial capacities of the body, yet it precedes the elaboration of artistic or scientific products, instead shifting its emphasis "on the concrete practices of fabrication and the media and materials involved - an erratic search that makes use of things and the draw exerted by things" (Mersch, 2015, p. 13). The educational capacity of this approach therefore sits in with the ability to observe one's making, without directing the focus towards the concomitant processes of understanding or arousal of interest in the product/subject.

Both arts and sciences are freed from the expectation to entertain, mesmerise, or deliver to specified results; instead, they are implicated in an event and its performance, grounded in the exploration of the ways in which concrete phenomena are observed and become visible or audible, and therefore amenable to perception. Trans-disciplinarity does not require in-depth knowledge of all disciplines, but its focus lies on understanding how knowledge is being produced; paying enough attention to what knowledge (or product) is being made, and how; who is involved in the co-creation process and who is excluded, and why; the choices of methods that are being made and why; and why boundaries are drawn by the different subjects, with their particular methods and perspectives (Osborne, 1990; Eisner, 1991, 2001). This approach is explored in this project as a methodology that enables all students from all levels of education to learn how to learn. On the one hand, by developing awareness of how different modalities of knowing across the arts and the sciences shape what is brought into view; on the other hand, by providing tools for changing perception; drawing on the sciences and the arts to reveal, bring to the surface, give voice, narrate, give visibility, and bring particular experiences into being.

2.5. Critique on the primacy of the scientific model

In order to give way to pathways of co-creation and transdisciplinarity, particularly in education, key obstacles must be identified and addressed. One central key problem in the didactics of science in schools is what can be called the primacy of the model over the phenomenon. This term is abbreviated but concise. In our view, the underlying problem plays a key role in all efforts to improve the teaching of a subject or its learning outcomes (Schulze Heuling and Schulze Heuling, 2023).

Natural science's ontology confronts us with the mechanisation of nature, (Dijksterhuis, 1961), where properties of objects have been classified as primary properties (measurable, e.g., size, mass...) and secondary properties (only existing in human consciousness as subjective phenomena conditioned by mind and senses, e.g., smell, colour, taste...). This division is commonly accepted, also by protagonists in the education system. Roth, McGinn and Bowen (Roth, McGinn and Bowen, 1998) for example found an understanding in student teachers that depicts an ontology based on mathematical laws and that sees deviations from idealised relationships as errors – thus not relating the understanding to nature but to an idealised model. Clearly, natural scientists capture the world in abstract models. This is essential because the transfer of information into a model supports understanding and explaining of complex phenomena, through a set of recognised variables in interaction. However, with every new generation inheriting the mathematical techniques the acknowledgement of transformation deceased, leading to self-evidence of scientific achievements. The abstract objects of science, such as models or formula, took on a life on their own cut-off from experiences, while at the same time meant to explain those. Thus, they were possessing an ontological status of truth and objectivity. Harvey (1989) described this process as Ontological Reversal, meaning abstract scientific or mathematical models are taken as more real than everyday reality since abstract models (or formula etc.) are seen as real causes behind every day experiences, constituting the ultimate reality behind our lifeworld. As a result, science is produced and understood only by a group of specialists who are "in the know".

This "professional knowledge" (Fleck 1935) is passed on through a process of simplification and thus becomes "popular knowledge". This means that, in addition to idealisation, the everyday tasks and routines of researchers, the dissonances and ambiguities, and the detours of scientific knowledge fade or even disappear. The epistemological dynamic of knowledge creation is no longer visible. In line with Ludwik Fleck's postulate of 'textbook' and 'popular knowledge' science, it is proposed that teachers encounter these types of scientific knowledge as the art of science in almost every teacher training programme. This pattern seems to be repeated in schools (Schulze Heuling and Wild, 2016).

2.6. Phenomenon-based STEM education

To overcome the limitations of the ontological reversal and textbook science, a transformative approach beckons - one that acknowledges and facilitates the complexity and ambiguity of real-life. In addition to the challenges brought to education through the ontological reversal, a typical science lesson fails to address the questions and capabilities of students and fails to acknowledge the complexity of reality. Educational experiments are typically prepared in a way that ensures the reliable reproduction of a phenomenon to illustrate and confirm the previously introduced model. While a teacher has control over the progression of a demonstration experiment, “hands on” experiments follow an even tighter recipe to ensure reliable conduct without causing deviating questions. Such hands-on or student-centred practical sessions are typically composed as a linear sequence of the following idealised format:

1. Take this and do exactly this with it!
2. Realise the following!
3. Let me explain it to you!
4. By the way, you can also find something like this here.

The dominant didactic approach perpetuates a standard, algorithmic approach to teaching science. Such a scripted conduct of an educational experiment in combination with the ontological reversal makes science education fail to bridge the epistemological gap between the model and real-life phenomena. However, little consideration is given to the uncharted territory that lies between models and the scripted generation of a phenomenon in an educational context. Müller and Schumann (2021) highlight that the doing of science, practices of sensing, noticing, creating and sharing, might exactly be the needed bridge between phenomenon- and model-based science content.
In response, SENSE. asserts that practices, the doing and the response to an action, act as conduits linking the disparate domains. The preceding deliverable (D3.4) highlights the central role of 'practical' engagement and reflective feedback in fostering meaning and understanding. Within this realm, SENSE. puts emphasis on embodiment and imagination. SENSE. puts also emphasis on transcending the rigidity of linear conduct, inviting other time concepts, such as circular or biological time, into the planning and conduct of an educational activity.

2.7. STEAM space and place

Loris Malaguzzi's assertion that "the classroom is the third teacher" resonates deeply in the field of education, highlighting the profound impact of physical spaces on teaching and learning. Indeed, the notion that the environment matters in education is undeniable - a premise we readily endorse. Schools, like any space, have a distinct essence that can shape the educational journey.

However, we disagree with the view that the environment acts as an authoritative teacher or a deterministic configuration that dictates specific educational outcomes. While certain pedagogical approaches advocate carefully designated corners and areas within classrooms, even in child-led settings, this approach can sometimes seem over-determined, restricting the fluidity of learning experiences. The danger lies in turning spatial design into a formulaic recipe for predetermined outcomes, a tendency that education often favours due to its inherent desire for predictability.

At SENSE.STEAM we propose an alternative view: the physical environment is neither an active teacher nor a predetermined path to fixed outcomes. Rather, it offers interactive possibilities, fostering a dialogue between the individual and their environment. It's a symbiotic relationship, a dance between human agency and physical reality, where imperatives are avoided.

Makerspaces, an increasingly popular concept in education, seem to embody this philosophy; when thoughtfully designed and maintained, these collaborative spaces encourage embodied exploration and innovative thinking in STEAM subjects. Makerspaces aren't rigid teachers; they want to be catalysts for experiential learning, where students design, experiment and create.

Similarly, repair cafes. These are hands-on spaces that model sustainability, knowledge sharing, and hands-on problem solving - hallmarks of STEAM. They reinforce the idea that our relationship with the environment isn't unidirectional; it's a give and take, a dialogue that can lead to novel solutions.

In the quest to break down barriers between science and art and making science more democratic, science in theatre is at the heart of this. This fusion of performance, imagination and evidence challenges traditional notions of knowledge, its creation and dissemination. Whether through research theatre, lecture performances or science slams, audiences are empowered to become creators of science, shaping their understanding through engagement and participation.

In conclusion, the classroom - or any space - isn't a teacher or a formulaic mould. It's a canvas for interaction, exploration and co-creation. By recognising the role of the environment as a partner in education, we embark on a dynamic journey where learning thrives through collaboration and fluidity. For a deeper read we refer to section 3.2.1 in this document.

2.8. Summary: Lessons learnt from literature

An overview of the current state of modelling STEAM shows that it's often seen either as an infusion of arts or as a transdisciplinary strategy that bridges arts and science for knowledge creation. This duality is evident in how STEAM is implemented in practice in different European projects. Recognising this is essential for understanding stakeholder perspectives and for creating an educational roadmap that provides accessible and sustainable access to its educational principles and content. The aim of SENSE. is to construct an inclusive roadmap for STEAM education, involving a wide range of stakeholders. By drawing on insights from international education policies, national curricula and socio-cultural contexts, the SENSE. initiative aims to establish a well-structured approach to shaping STEAM education in Europe. This involves understanding the norms, values and social representations of the target audience, as well as the barriers and obstacles they face in accessing and participating in such initiatives.

3. The SENSE. approach to STEAM education

SENSE. proposes, tests, and implements a methodology for the power of transformation through education - SENSE.STEAM. The SENSE.STEAM methodology is a fusion of a theoretical model (elaborated in this document) and the practical and lived pedagogy, whose foundations we explain in D3.4. SENSE.STEAM uses scientific and artistic inquiry with reflective feedback to promote real-world learning that is culturally relevant and meaningful to students in their local communities. SENSE. STEAM proposes the constant interaction between the model and practice of STEAM, particularly through the integration of theoretical achievements and practical knowledge through reflection, peer feedback and the appreciation of embodied and tacit knowledge.

After having presented the current body of theoretical conceptions of STEAM in chapter two, now dive deeper into the foundations of the SENSE. methodology, its key components, and core embedded pathways. We understand this model as a living construct, a model that is open to change and shall be transformed by the co-creation of stakeholders and which will be constantly shaped and reshaped in dialogue with the *doing* of STEAM.

This chapter describes the SENSE. approach first in section 4.1 with a description its four educational key components, the building blocks that are designed to be integrated into all implementation of SENSE. These key components were designed with the backdrop of a core ethics and priorities, described as the core embedded pathways of SENSE. in section 4.2.

3.1. Educational key components in SENSE.

Building on the extensive background experience and research conducted by lead members of the project consortium, the SENSE.STEAM model is grounded into four building blocks (Fig. 1):

1) Learner Centred pedagogy: a radical shift from viewing learners as knowledge receivers to active creators of their own knowledge, promoting self-directed learning and empathy with others. (section 4.1.1)

2) Reflective Feedback: "Feedback" drives development and transformation by prompting individuals to assess their emotions, thoughts, actions, and impact, fostering ongoing processes. Reflective feedback covers introspection and interaction, enhancing personal encounters, empathy and engagement. This connection expands to humans and non-humans (such as feedback provided through interaction with an object), nurturing a holistic perspective of being in the world. (section 4.1.2)

3) STEAM inquiry: In STEAM inquiry various elements of knowing and sense making converge embodying experiences, probing questions, recognizing patterns, forging connections, showcasing empathy, embracing uncertainty, shaping significance, taking action, introspective reflection, and critical assessment. This framework finds application not only within the arts but also in the realm of STEAM research. (section 4.1.3)

4) Citizen Science and Art practices: enabling school students to liaise directly with the public, as both science makers and science users. An Art-based Citizen science approach will facilitate engagement with both, scientists and artists, artistic interventions, theatres and science labs to explore, discuss and reflect together on matters that are important to the community. (section 4.1.4)

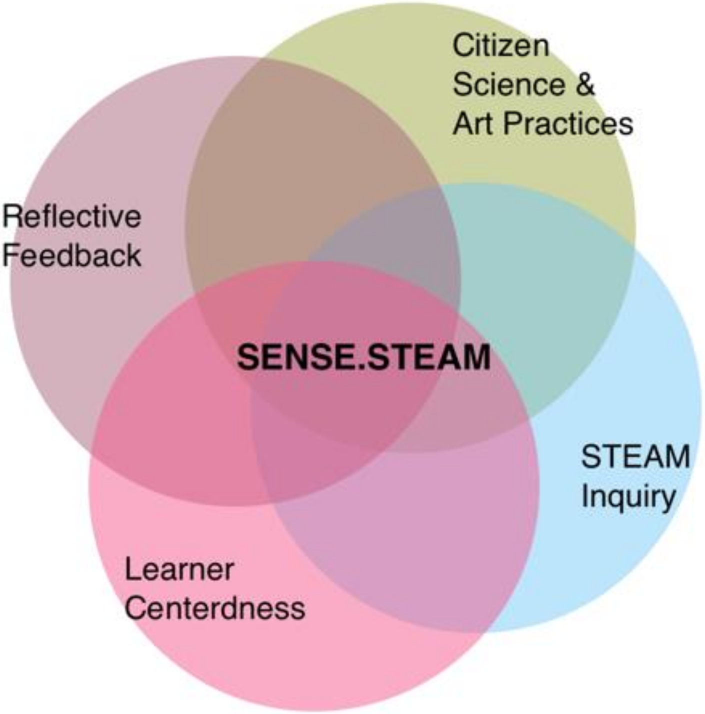

Figure 1: The SENSE. model for STEAM education brings together four interacting key domains.

3.1.1. Learner centredness

Traditionally, education has been confined to technicist narratives that cast educators as purveyors of content and assessors of outcomes. This mechanistic view suited a world increasingly defined by predictability and measurement. However, the transition revealed the limitations of rigid control in the face of uncertainty. Educators found themselves in unfamiliar territory, departing from established roles and scripted methods.

This raises an urgent question: What does this experience reveal about the nature of education? How does it reshape the roles, perspectives and circumstances of educators across the whole learning continuum? Education, as an embodied practice, thrives on complexity and a willingness to embrace ambiguity. Adopting a stance of 'not knowing' cultivates a deeper understanding of what remains unexplored, fostering curiosity and personal growth (Van Manen, 2023).

This paradigm shift calls for a rethinking of teaching and educational narratives. In a landscape that challenges linear approaches and demands adaptability, a shift towards exploration, surprise and imagination emerges as essential. Eisner's (2002) vision of an educational culture that values becoming over being, exploration over discovery, and the metaphorical over the literal resonates as we redefine pedagogical strategies.

A true commitment to learner-centred education requires us to consider the core questions that drive our profession. How have our roles as educators changed? This discourse goes beyond pragmatic adaptations to the very essence of education. By fostering an educational culture that values growth, imagination and individuality, we create a transformative learning journey that equips learners for a dynamic world.

Educators have a unique opportunity to seize this moment of reflection, to challenge conventional norms and explore narratives that transcend established paradigms. By fostering an atmosphere that values exploration, embraces uncertainty and celebrates creativity, we lay the foundation for learner-centred education that equips students not only with existing knowledge, but also with the skills they will need in a future where adaptability and innovation are paramount. In doing so, we uphold the ethical responsibility of education - to prepare learners not just for known outcomes, but to empower them to navigate the unknown with confidence.

Learner-centred education places a strong emphasis on recognising and valuing the individual subjectivity of each student and tailoring the learning experience to the moment. This approach shifts the focus from a one-size-fits-all model to creating adaptive and personalised learning environments that empower students to take an active role in their education. By recognising different perspectives and experiences, this approach promotes engagement and self-motivation as well as relevance and a deeper understanding of subject matter.

3.1.2. Reflective feedback

Both, learning and STEM are social undertakings. While it is well established that the social process of reflection is crucial to the creation of understanding, it has rarely been recognised in STEM education that research itself is created through socialisation and culture. In the SENSE. methodology, reflective feedback integrates the personal, community, identity and, importantly, the transformative nature of SENSE. activities into existing frameworks of STEAM education and practices that involve sensing the world. The arts offer additional entry-points for informed reflective feedback to assist learners in improving their knowledge, skills, attitudes and understanding of STEAM and its practices.

For the purposes of the SENSE. project, we define reflective feedback very generally, to include all forms of reflection and communication (and reflection-communication) that allow learners to evaluate and improve their own experiences and their own connection to the world around them. This includes both formal and informal feedback, self-reflection, peer feedback, feedback from teachers or facilitators, intersubjective feedback with humans and non-nonhumans, and the reflective feedback that occurs either in small moments or over longer periods of times that cannot be enunciated or pinned down so easily.

By taking a broad and inclusive approach to reflective feedback, we hope to capture the full range of experiences and perspectives that can contribute to meaningful learning and growth. Through this exploration, we aim to highlight the importance and benefits of reflective feedback in promoting STEAM and sensory education and provide examples of effective techniques and strategies that can be used in various contexts.

Two central themes of reflective feedback in the SENSE. project are co-constitution and embodiment. Co-constitution refers to the idea that learning experiences are not solely determined by the individual, but are also shaped by the group, community, and place in which they occur. This means that reflective feedback must consider not only the individual's own experiences, but also the social and environmental factors that contribute to their learning. Embodiment, on the other hand, emphasizes the importance of the whole person in the learning process, including their senses, cognition, identity, and body. By expanding the sense of self to include not just the individual but also on other scales, for example of at the scale of molecules, body interactions, rooms, neighbourhoods, towns, regions, continents, and worlds, we can create a more holistic and inclusive approach to reflective feedback that considers the full range of human experience.

While the central themes of co-constitution and embodiment in reflective feedback are supported by previous evidence-based research in education and feedbacking techniques used in art practices, they also represent a new approach to addressing the persistent problems in science education identified in this document – the failures to promote continued interest and curiosity in the process of knowledge-making, innovation, and creation. By adopting a more holistic and collaborative approach to reflective feedback, we can create a more inclusive and engaging learning environment that promotes both scientific and artistic inquiry. This approach aligns with the central tenets of our project, including reverse ontology and phenomenon-based STEM education, which emphasize the importance of exploring complex phenomena and taking a multi-disciplinary approach to learning. By building on previous research and taking a new approach to reflective feedback, we hope to inspire and engage learners to continue exploring the wonders of the world and to develop a lifelong love of learning.

Evidence-based feedback practices in education

Reflective feedback is an essential aspect of learning that has been widely studied and discussed in academic research. The articles included in this section provide insights into the nature of feedback, its features, and its impact on student learning. Three systematic reviews of feedback in education, all published in the past fifteen years, establish the state of practice and evidence in feedback in educational settings.

Hattie and Timperley (2007) define feedback as information provided by an agent (such as a teacher or peer) regarding a student's performance or understanding. They argue that feedback is a consequence of performance and that it has the power to enhance or hinder learning, depending on how it is provided and received. They highlight the critical importance of good feedback and propose a model of feedback based on three major feedback questions: “Where am I going? How am I going? And

Where to next?" (p. 102). These questions assist in identifying discrepancies between what students understand and what teachers aim to be understood. They argue in conclusion that effective feedback at the levels of task, processing, regulatory and self are critical and require skill, care, time and give-and-take from teachers and students.

Shute (2008) focus on 'formative feedback', "information communicated to the learner that is intended to modify his or her thinking or behaviour for the purpose of improving learning" (p. 154). Shute discusses the key features of effective feedback, including verification, elaboration, complexity, goal-directed feedback, motivation, scaffolding, and timing. Shute argues that effective feedback should be tailored to the individual student and should be delivered in a way that promotes learning and motivation.

Torres, Strong, and Adesope (2020) conducted a systematic narrative review of 77 studies on reflective feedback in a college setting. They found that effective feedback was content situated, dialogic, empathic, and positioned students as both fluid and vulnerable. Content-situated feedback is feedback that is specific to the task or content being learned, while dialogic feedback involves a back-and-forth exchange between the teacher and student. Empathic feedback is feedback that takes into account the student's emotions and feelings, while positioning students as fluid and vulnerable acknowledges their growth potential and the challenges they may face.

Feedbacking techniques in art and geography education and practice

In addition to the academic articles previously mentioned, feedback techniques from the arts can provide valuable insights into the nature of feedback and its impact on learning. The Das Arts feedback method and Barbican Creative Learning feedback techniques are two examples of such techniques that have been developed and used in the arts. We also include participatory mapping activities from geography, which draw especially upon feminist and anti-colonial scholarships to bring together multiple approaches, perspectives, and stories for intensive exploration of space and place, an important pillar of the SENSE. methodology (see section 4.2).

The Das Arts feedback method is a feedback process developed by the Das Arts Master of Theatre program in Amsterdam. This method involves a structured process that includes both written and oral feedback, as well as group feedback sessions. The process begins with a self-evaluation by the artist, followed by a peer evaluation and feedback from mentors and experts in the field. The process culminates in a public presentation of the work, which serves as a final opportunity for feedback and reflection.

The Barbican Creative Learning feedback techniques (2022) are a set of feedback techniques developed by the Barbican Centre in London to support arts learning and creative development. These techniques are designed to be inclusive and accessible to a wide range of learners, including those with disabilities or learning difficulties.

Participatory mapping activities such as deep mapping and community mapping (Buttimer, 1976; Tuan, 1977, 1979; Massey, 1994, 2008; Abd-El-Khalick *et al.*, 2004; Kavanagh, 2018, 2020a, 2020b; Ingold, 2019) are activities that allow the bringing together of multiple approaches, perspectives, methods, and stories for an intensive exploration of a particular place, with possible focuses on a relevant topic or a recent activity. Participants can gather around a large-scale map of an area identified as relevant to the group – capturing possibly a sense of 'home', 'community,' 'local' – and mark where they experience emotions, sense, feelings, thoughts, ideas, and more depending on the particular focus of the activity. This form of feedback allows for accessible, engaging, clear, flexible, and practical production of feedback material, conversations and for multiple understandings of issues and places.

The importance, significance, and usefulness of these feedback techniques lie in their ability to promote self-reflection, collaboration, and creativity in learners. By incorporating feedback techniques from the arts into STEAM and sensory education, educators can create a more inclusive and engaging learning environment that promotes self-expression and personal growth. These techniques can help learners to develop their skills and creativity, as well as build their confidence and self-awareness. Furthermore, these feedback techniques are transferable to other areas of life and work, making them valuable tools for lifelong learning and personal development.

Reflective Feedback in SENSE. STEAM

The application of reflective feedback in the SENSE. approach to STEAM and sensory education builds upon evidence-based lessons on feedback in education and artistic and scientific research practices. The two key themes that underpin our approach are an attention to co-constituted experiences and embodiment in how the SENSE. approach generally understands, encourages, and is built upon reflective feedback from all involved. Co-constituted experiences emphasize the interconnectedness of individuals, groups, communities, and places in shaping and influencing learning experiences. Embodiment, on the other hand, highlights the importance of understanding the sense of self as being embodied, encompassing senses, cognition, identity, and the physical body, and how expanding this sense of self to different scales can foster a more inclusive and holistic approach to learning.

Our attention to co-constituted experiences in reflective feedback recognizes that learning is not an individual process but rather a collaborative and dynamic one that is shaped by a range of factors. By positioning learners as active participants in their own learning, and by involving groups, communities, and places in the learning experience, we aim to create a more meaningful and engaging educational experience. Co-constituted experiences, therefore, consider the context in which learning occurs, and the role of various stakeholders in shaping and influencing the learning experience. By integrating this approach into our use of reflective feedback, we can foster a more inclusive and collaborative learning environment that recognizes the interdependence of different individuals, groups, and communities.

Embodiment refers to the idea that individuals' senses, cognition, identity, and body are interconnected and influence each other in complex ways. In the context of STEAM and sensory education, this means expanding the sense of self to include self at various scales, such as the molecule, person-scale, room, neighbourhood, town, region, and beyond. Embodiment is a crucial aspect of reflective feedback because it enables individuals to reflect on their experiences in a holistic and nuanced way. By considering the interplay between their senses, cognition, identity, and body, individuals can gain a deeper understanding of their experiences and how they relate to the world around them. This, in turn, can lead to more effective and meaningful feedback that considers the whole person and their lived experiences. In the SENSE. approach to STEAM and sensory education, embodiment is a key component of reflective feedback, as it helps to promote a deeper connection to the world and a more nuanced understanding of the self and others.

3.1.3. Renewing artistic and scientific relationships – STEAM inquiry

Building on the insights of the ontological reversal (see 2.5), phenomenological education and real-world orientation, SENSE. wants to break new ground in the generation of multi-modal knowledge for future-making education. The following paragraphs discuss artistic research and what is traditionally considered to be inquiry learning in science education[1].

Artistic research and research creation
The supposedly opposing relationship between art and science has been up for debate for some time. Classical attributions are being negotiated, such as whether artists conduct research and scientists create aesthetic works, whether artists proceed systematically in their work and scientists are guided by intuition or impulse. For SENSE. it is central that this dissolution of disciplines and forms of knowledge makes dialogue possible.

In recent decades, the exponential development of projects putting scientific and artistic productions into dialogue has taken place in many spheres of activity such as university and educational projects, industrial, and technological activity, or the programming of cultural institutions. In the field of research, whether in the sciences or in the humanities, a growing number of researchers in various disciplines are resorting to methodological choices that involve, for example, the use of artistic devices such as film, performance, theatre, installation, sound art, scores, etc., or that imply the borrowing of artistic strategies, tactics, and protocols.

The range of research methodological options and investigative tools is gradually expanding to respond to the plurality of knowledge and disciplinary frameworks. There are many examples of experimental forms of collaboration or use of

[1] The historical connections between arts and science are briefly elaborated in Annex 1.

experimental protocols from artistic practices. The place of creation in the dynamics of research seems to have acquired a new centrality, which translates, among other things, into the setting up of training programs and specific projects that seek to articulate artistic and scientific research. The conception of new formats for the production and dissemination of knowledge, such as exhibitions, performances, theatrical devices, or innovative editorial and publishing forms[2], draws a landscape of intense formal and conceptual experimentation. The integration of these new tools is now part of the methodological concerns of many researchers who question the use of artistic formats, its impact on the process of construction of the research subject, the epistemological stakes that this raises while trying to maintain scientific rigour. This methodological permeability between different disciplines, which makes it possible to broaden the potential for capturing, translating, and sharing sensory-based experience, is not without its frictions.

Efforts to merge scientific exploration with creative processes are often referred to as research-creation, involving different methodological perspectives, activities, and a key role for design. Design's growing fusion with fields such as contemporary art is visible in trends such as critical design and design for social innovation, which emphasise contextual links and material literacy. This evolving landscape also includes the importance of material literacy in pedagogical contexts, supported by initiatives such as the 'Making and Knowing Project' led by art historian Pamela H. Smith at Columbia University or the SENSE.Lab, laboratory for thought in motion, founded by Erin Manning.

The convergence of the arts and sciences has significant implications for education. The performing arts in particular align seamlessly with science and maths education, using choreography, movement analysis and immersive experiences to illustrate complex scientific concepts. The dynamic and interactive nature of artistic methods encourages active engagement and deeper understanding.
Performing arts are most often associated with STEM education because of their adaptability to collective work in larger groups (Stolberg, 2006). However, all art forms allow for dynamic and performative artistic modelling or inquiry in the classroom. University educators are also blending STEM and performing arts; Lucy Irving and Carl Senior offer YouTube tutorials that use choreography to explain statistics (Irving, 2015), while Schultz and Brackbill (2009) used rhythmic dance to improve medical students' ECG interpretation.
The arts have also shown promise in student assessment (Katz, 2016; Veen, 2012; Knowles & Cole, 2008; Macintyre et al., 2007; Soep, 2005). However, mainstream STEM education often presents subjects as static, coherent and linear, whereas STEAM provides a responsive pathway to 'whole STEM learning' (Allchin & Zemplen, 2020) and encourages engagement with the complexity of STEM. STEAM education encourages students to be 'science makers', countering disinterest and promoting

[2] See for example the project .able (*.able Journal - About*), initiated by the Chaire arts & sciences (École Polytechnique, École des Arts Décoratifs – Université Paris Sciences & Lettres (PSL) and the Fondation Daniel et Nina Carasso), an image-based muti-platform journal at the intersection of art, design and sciences.

inclusivity and cultural responsiveness in classrooms (Reif and Grant, 2010; Gedžūne and Gedžūne, 2011).

Traditional inquiry-based learning in science education

Inquiry-based learning in science education has gained traction over the last two decades, lauded for its effectiveness in both understanding science content and fostering students' interest and connection to the subject. This approach has been endorsed in reform documents (Abd-El-Khalick et al., 2004; Rocard et al., 2007; Crawford, 2014; García-Carmona, 2020) and is exemplified by the European Commission's Rocard Report (2007), which highlights its ability to stimulate interest, collaboration and relationships across different learning settings. The Norwegian curriculum also emphasises the link between inquiry and creativity (Ministry of Education and Research, 2017), which is echoed in the German, Austrian and Swiss curricula that emphasise awareness and questioning (Labudde and Börlin, 2013).

In essence, inquiry in science encompasses both how scientists explore the world - scientific inquiry - and how students learn and teachers teach science in schools through inquiry-based learning and teaching (IBL/IBT) (Crawford, 2014). This dual interpretation can be traced back to John Dewey's ideas on natural thinking and learning (1910). Dewey advocated a shift in education to reflect the alternation between sensory inputs and their interpretations, which he called the 'felt problem' (p. 72). He proposed that learning involves working with sensory inputs, suggesting possible interpretations, testing them through new observations, or reflecting on familiar experiences, a process also followed by scientists (Dewey, 1910).

Several scholars, including Ludwik Fleck, Harvey, Reggio pedagogy and Martin Wagenschein, have addressed holistic understanding from different perspectives. However, there remains confusion within the research field about the precise meaning of inquiry-based learning (Crawford, 2014). This divergence includes views ranging from unguided, student-driven inquiry to all kinds of hands-on activities, even traditional cookbook exercises (Blanchard et al., 2010).

The complexity of inquiry is evident in its objectives: the conceptual domain develops understanding of scientific ideas, the epistemological domain explores knowledge generation, the social domain cultivates communication and cooperation skills, and the procedural domain imparts methodological skills (Duschl, 2008; Furtak et al., 2012). Myriad studies dissect inquiry processes, practices, virtues and views of knowledge, contributing to a multifaceted concept (Osborne, 2014; Bailin & Battersby, 2016).

Knain and Kolstø (2019) advocate aligning teacher control, learning goals and complexity. For conceptual understanding, lower complexity is favoured in order to encourage diverse reasoning. Semi-open activities, which give students control over data collection and expected outcomes, are suitable for learning scientific reasoning. Open activities give students decision-making power at all stages, which is suitable for developing complex knowledge about social science issues (Sadler and Dawson, 2012).

In recent years, scientific practices have gained prominence as a substitute for inquiry-based learning, focusing on modelling, argumentation, and integration of skills (National Research Council, 2012; Crawford, 2014; García-Carmona, 2020). Creative processes, emotions and aesthetic experiences have also been recognised for their role in students' observations and meaning-making (Prain and Tytler, 2012; Wickman, Prain and Tytler, 2022).

Creating STEAM inquiry
Initiating the project, our goal was to create an inclusive inquiry, merging artistic and scientific knowledge practices. This approach would encompass somatic and tacit knowledge, value diverse epistemologies, and prioritize learner involvement.

After a year, we recognized the need to go further and replace the narrow confines of "inquiry" due to its biases. We suggest using "STEAM enquiry" to better encompass the various knowledge creation forms in STEAM. Changing from "inquiry" to "enquiry" signifies a broader shift in thinking.
"Scientific inquiry" emphasizes systematic analysis and problem-solving, while "scientific enquiry" takes a holistic, exploratory approach that embraces uncertainty and curiosity.

For STEAM education, "enquiry" transforms traditional STEM teaching. It emphasizes diverse epistemologies, reveals knowledge's social and cultural aspects, and prepares learners to anticipate challenges.

In essence, the shift to 'STEAM enquiry' underscores that education is about fostering a mindset of embodied cognition, empathy, co-creation, questioning, and growth. It equips learners with skills to drive innovation, navigate uncertainty, and shape the future. SENSE. draws from models like 'Aesthetic Education, Inquiry and the Imagination' (Greene, 2001; Holzer, 2005). This model, derived from aesthetic learning, comprises nine capacities including deep noticing and empathy. Physicists find five capacities directly relevant to their work (noticing deeply, embodying, questioning, identifying patterns, and making connections) (Weisskopf, 1976; Veen, 2012; Boy, 2013).

3.1.4. Towards citizens involvement in science and arts

Citizen science and arts interventions are ways to increase citizen engagement in science and the arts. Both emphasise active participation and democratising access to knowledge, in line with the collaborative nature of STEAM education. They raise public awareness, educate about important issues and stimulate conversation, with art fostering personal connections and citizen science empowering participants to contribute to research.

Collaboration is essential in both areas, with citizen science involving scientists, volunteers and policy makers, while arts interventions bring together artists, community members and experts to create impactful projects. Ethical concerns, including privacy and representation, apply to both. Both foster community connections, as citizen science connects like-minded individuals and artistic interventions engage communities around shared issues.

From a policy level, the European research policy envisages scientific research oriented by specific societal goals, such as the Sustainable Development Goals (SDG) of the United Nations. Just for illustrative purposes, a recent EU report (Mazzucato, 2018) imagines mission-oriented research. The report already includes citizens in this effort stating: “Bold missions can provide new syntheses that are today impossible and thus will hopefully achieve the breakthroughs that are urgently needed to solve some of the most pressing issues facing our citizens” (p. 7). The report also discusses active participation: “Citizens can possibly be mobilised to become active participants in missions, for example by cleaning plastics from beaches or by providing real-time monitoring data as enabling technologies develop and become more universally present in society” (p. 20). European research policy also supports Open Science which not only favours transparency and accessibility of scientific knowledge but also promotes democratisation of science, knowledge co-production or the active involvement of citizens, groups, or communities in scientific research with for instance Citizen Science practices.

Citizen science and artistic practices are practices that can harmoniously enrich STEAM education and address the general public, deepen involvement and co-creation of STEAM of all citizens. Both approaches empower students to actively engage with their environment and make meaningful connections. These participatory methods resonate with STEAM's emphasis on experiential learning, critical thinking and collaboration.

Citizen science gives students the tools to engage with the natural world through data collection, analysis and problem solving. This immersive engagement aligns well with STEAM principles and fosters a sense of ownership of scientific inquiry and environmental stewardship. The methodology evolves scientific practices by adapting them to participatory data collection, promoting inclusivity and challenging power dynamics. It amplifies marginalised voices, strengthens community ties and stimulates public discourse. Through collaborative engagement, it promotes the co-creation of knowledge, catalysing collective action and informed policy recommendations.

Similarly, artistic interventions offer a dynamic approach that encourages students to engage deeply with their environment. By immersing students in artistic processes, analysis and problem solving, these interventions cultivate a sense of ownership of creative exploration. This aligns seamlessly with the experiential learning and collaborative expression of STEAM. Art interventions transform traditional approaches by infusing them with participatory artistic practices, amplifying marginalised voices, challenging societal norms, and encouraging introspection about power dynamics. These interventions unite individuals and communities, fostering collaborative exploration and transforming spaces into interactive hubs of creative dialogue.

In addition, both methods embody the holistic approach of STEAM education. Embodied cognition, a common principle, asserts that learning is intertwined with physical experience. In CS, students gather data through their senses, embedding understanding in their bodies. In art interventions, sensory engagement fosters deeper connections to the subjects. This shared embodiment moves learning beyond theory to experience. Integrating artistic interventions into the CS framework enhances embodied learning, provides a creative outlet for expressing scientific concepts, and enriches students' educational journeys.

Incorporating citizen science and artistic interventions into STEAM education not only reinforces experiential learning and collaborative exploration, but also fosters a holistic understanding of the world, where scientific inquiry and artistic expression harmonise to shape informed, engaged citizens.

3.2. Core embedded pathways to SENSE.

In this section we explore the intricate web of core embedded pathways that underpin the SENSE. methodology and highlight the transformative potential they hold. Our exploration begins with Section 3.2.1, which delves into the realm of spatial dynamics and its role as a catalyst for change. Next, section 3.2.2 explores the profound importance of social inclusion and how it is a cornerstone of SENSE.'s mission. Section 3.2.3 addresses the persistent issue of gender inequality in STEM, critically examining the daunting challenge of breaking the glass ceiling. Finally, section 3.2.4 highlights the vital contributions of arts and culture, providing insights into the societal value of heritage, museums and galleries within the broader vision of SENSE. Through this multi-dimensional exploration, we seek to uncover the interconnected threads that weave together the diverse pathways that lead the SENSE. initiative towards its transformative goals.

3.2.1. Space as a driver of change

The ecological perspective
Ecological psychology, as pioneered in the works of J.J. and E.J. Gibson (Gibson, 2015), established an approach to cognition that aimed to overcome the traditional dichotomy of perception/action, organism/environment, subjective/objective, and mind/body (Lobo, Heras-Escribano and Travieso, 2018). The ecological approach assumes that the body interacts with its environment through a complex feedback loop that attributes agency mutually: Every being shapes its environment, and vice versa.

“It is often neglected that the words animal and environment make an inseparable pair. Each term implies the other. No animal could exist without an environment surrounding it. Equally, although not so obvious, an environment implies an animal (or at least an organism) to be surrounded.” (Gibson, 2015, p. 8)

Although the physical environment is an objective reality independent of the inhabiting beings, the interaction is relational to each agent and non-determined. It is worth noting that Gibson distinguishes between “physical reality” and “environment”, with the former describing the configuration of matter and the latter the unique relationship between being and the physical world. To understand this dynamic model, the terms “affordances” and “perception-action loop” are fundamental.

Perception-Action Loop
Gibson saw perception as an active, embodied process where the human senses and body (eyes move, hands touch, the head changes position etc.) constantly adjust to the reality of the environment, give feedback to the brain, adjust the perception according to the input and so forth. However, by doing so, beings change the environment dynamically, which again alters the perception and so on. This way, human beings and the environment are part of an intrinsically interlinked, recursive action-perception system.

Although this model captures the complexity of human interaction with the physical world, it does contain the danger of over-emphasising the absolute relativity and, therefore, limited transferability of real-world interventions. This would also contradict our intuitive understanding of predictable behaviour conventions. To mediate between subjective choice and ontology, the concept of “affordances” allows for operability and – though limited - predictability of the physical environment.

Affordances
Gibson (2015) introduced the concept of affordances to describe how the physical environment offers opportunities for actions to beings. A handle invites you to pull, a surface to walk, a button to push etc. It is worth noting that Affordances <u>do not</u> describe physical properties. They are configurations that offer a range – but not an unlimited number – of actions to beings. However, Gibson defines them as “relative to the animal. They are unique for that animal. They are not just abstract physical properties. They have unity relative to the posture and behaviour of the animal being considered. So, an affordance cannot be measured as we measure in physics” (p. 127).

Human beings perceive the world as a place that offers action possibilities. How these possibilities are taken up depends on many factors, not least the abilities of the individuum. A stair, for example, can – depending on the actor’s size and intention – be used to climb or as a place to sit. It surely is less suitable for sleeping unless the actor is very small – for example, a baby - or very intoxicated. In other contexts, a stair can be used as the base to display artefacts or as a place of physical exercise. Or as a raked seating arrangement to provide better vision to spectators. Or as a stage for a group to be photographed. Or as a mere representative architectural element visually mediating between different levels – and not to be "used" at all; and so on and on.

This way, affordances describe how a certain physical configuration offers a range of activities relative to the user's disposition. And there is a certain probability – but no certainty - that it will be used in the intended manner. Thus, the concept combines objective conditions and subjective choice without pre-determining the course of action.

In the 1990s, Don Norman transferred the concept of affordances into the design world (Norman, 2013). From there, it found its way into many areas of architecture, such as workplace organisation (Fayard and Weeks, 2014) or "spatial affordances" (Sailer, 2018). Although no single accepted or used definition of the term exists, its core assumption of a delicate balance between the "real" physical environment and individual choice provides a pragmatic understanding of spatial arrangements as enabling agents for human actions - without running into the trap of normative determinism. Especially for complex design tasks like schools, it offers a rich inspiration to create spaces that provide students with a broad range of action opportunities, and by doing so, guiding - or better embodying - varied enquiry processes without becoming too restrictive.

Space

Since the "spatial turn" of the 1960s and 1070s (Guldi, no date), which emphasised the importance of place and space in social science and the humanities, a complex and multi-layered academic discourse has developed, fundamentally changing how architects and urban designers understand the impact of the built environment. Within the wide spectrum of this discourse, scholars like Bill Hillier, Adrian Leaman, and Kevin Lynch were instrumental in developing a theory of space that aimed to inform the practice of architectural and urban design. (Hubbard and Kitchin, 2011).

Especially Hilliers work, later commercialised as "Space Syntax", was and is highly influential for understanding what space means for the designer. According to Hillier, architecture is different to "normal artefacts", such as a cup or knife, as it orders volumes of space in which many artefacts exist. While both - buildings and artefacts - share the properties of functionality and appearance, buildings "have a peculiar property that sets them apart from other artefacts and complicates the relation between usefulness and social meaning. (…) They are incomparable in that they also create and order the empty volumes of space resulting from that object into pattern. It is this ordering of space that is the purpose of a building." (Hillier and Hanson, 1989, p. 1). Space is an ordering principle, highly relative but with a distinct impact on the user.

From this model, we developed the 4-circle diagram *Function, Appearance, Environmental Conditions and Space*, which offers a way to inform the analysis and design strategies of the built environment. Function and appearance have long been part of the classical canon of architectural theory. While this is not the place to venture into the endless field of discussion, reaching back to Vitruvius.

Environmental conditions – temperature, light, air quality, noise etc. - are also not new but research in this field has been particularly intense in the last decade with many experiments showing significant correlations. (Villarreal Arroyo, Peñabaena-Niebles and Berdugo Correa, 2023). While these aspects are typically part of building code a more nuanced use has rarely been researched with educational environments. However, for an educational model that emphasises the multi-sensory aspect of learning, the more target use of light, smell or tactile sensation will be worth exploring.

While function, appearance and environmental conditions have been well accepted ingredients of the architectural discourse, "space" as an explicit category is a more contemporary addition. Architects have of course always arranged and organised architectural space intuitively, always within the limits of cultural and technical conventions. Still, space as an independent, operational design category has only come to the forefront in the last 50-60 years.

Researchers from all fields, such as geographers, behavioural psychologists, or neuroscientists, have highlighted how spatial conditions are fundamental to how we think, live, behave, form social relationships etc. Cognitive studies, for example, have shown that users think more open-ended and creatively in rooms with tall ceilings. In contrast, spaces with low ceilings facilitate tasks that need more focused work (Meyers-Levy and Zhu, 2007). Other works have shown how certain spatial arrangements improve the flow of information and, thus, health outcomes in hospitals (Sailer, 2021). Especially the field of workplace research has benefitted massively from an improved understanding of how spatial relationships influence outcomes. The link to ecological psychology is almost natural. Certain spatial arrangements offer – i.e. afford - certain behaviour patterns, the perception of space is highly active and spatial configuration dynamically changes within an interaction loop between user and environment.

For educational spaces, this research is highly relevant. The traditional classroom, for example, is a classic example where a spatial configuration "affords" a certain type of behaviour. It is a simple, ideally slightly oblong box with rows of chairs and tables directed to a teacher and visual resources at the short end. The classroom is an efficient spatial setting that helps a potentially diverse group of individuals sit still together and focus on a guided and formalised knowledge exchange, reducing the need for active behaviour management. Its design muffles, controls, and reduces the sensory "noise" to streamline the visual and aural information intake. This way, the traditional classroom deliberately limits sensory diversity, sets clear spatial boundaries and direction, and imposes a standardised learning behaviour on students.

The classroom example is useful for highlighting the importance of the two other dimensions of the presented model, “appearance” and “functionality”, which can immensely impact attainment performance (for example Tanner, 2000; Barrett *et al.*, 2013; Villarreal Arroyo, Peñabaena-Niebles and Berdugo Correa, 2023).

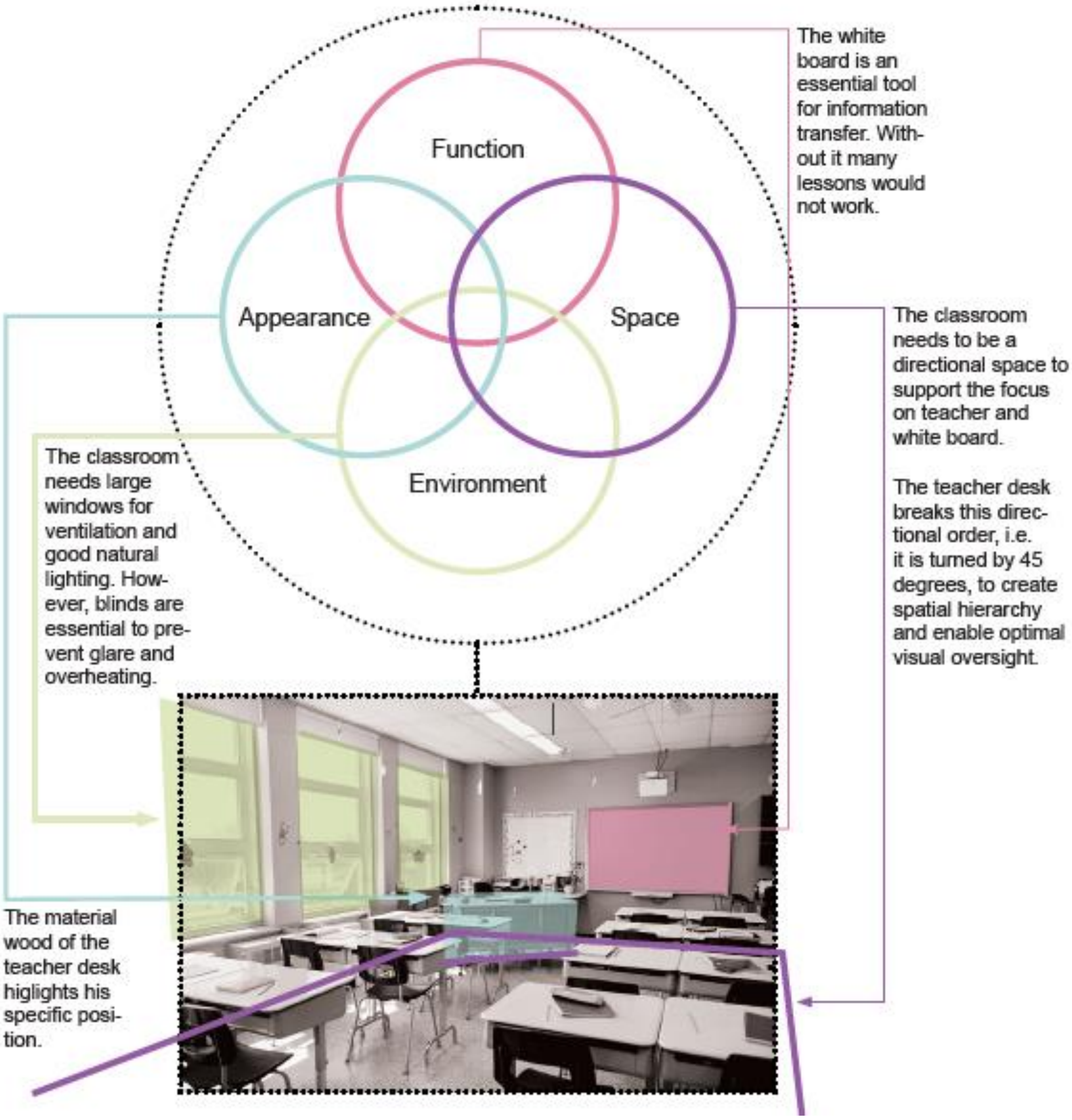

Figure 2: Analysing a traditional classroom through each of the four dimensions

In Figure 2, the teacher’s desk is wider than the students’ desks to accommodate more resources. It is also the only furniture piece made from wood, differentiating its appearance from the students’ desks. Both aspects highlight the prominent role of the teacher. Finally, the slightly turned placement of the teacher’s desk singles it out and gives the teacher better spatial control over the class. All three aspects - appearance, extended functionality, spatial relationship - work together to “afford” students to sit still and concentrate on information exchange and intake.

This example also shows that the analytical split into four different categories is artificial, i.e., appearance, environmental factors, functionality and spatial arrangement are intrinsically interrelated and amalgamate into a complex system, often impossible to "dissect", with clear causalities impossible to establish.

However, reflecting each of the four aspects offers plenty of operational opportunities to devise affordances that provide a wider spectrum of actions than a reductionary environment like the traditional classroom. It is widely acknowledged that changing the layout of students' desks, removing the whiteboard, or the teacher's desk can tremendously impact how students participate in lessons (Smith, 2017; Tobia *et al.*, 2022). However, what happens if a class takes place in a forest, in darkness, or if the classroom floor is sloping? What if students are allowed to change the colour of the walls before every lesson? What if there is a stage instead of a blackboard, or students are not allowed to write for the day while having to create abstract sculptures replacing written notes?

Reflecting on the impact and opportunities of the learning environment is of central importance for the STEAM.SENSE concept with its emphasis on open-ended and multi-sensory enquiry.

Enabling and explorative aspects of the use of space

In the first two sections of this chapter, we highlighted the complex relationship between individuum and their environment, where objective and subjective conditions are in a delicate balance. The reflection and analysis of the ingredients of the design ingredients of the learning environment - so the hypothesis - can support the SENSE. approach in two ways: Space as an enabler but also as a tool for active exploration.

Space as enabler

Many current STEAM practices are guided by a "learning by doing" approach, incorporating a broad spectrum of activities, like making artefacts, intense social interaction, enacting knowledge, using media, etc. Traditional classrooms restrain these types of STEAM experiences with limited spatial and functional offers: spaces are too small, tools are not available, lighting doesn't allow certain activities etc. Contemporary STEAM spaces are, therefore, larger multifunctional workshops with flexible open-plan layouts, which can enable these types of activities. However, large multifunctional spaces that maximise STEAM functionality can often be inefficient, i.e. too expensive, or pose behaviour challenges. To design these kinds of STEAM facilities, architects must, therefore, work intensively to harmonise spatial arrangement, appearance and functionality with budgets and other school requirements. Moreover, these spaces need to provide an inspiring environment that strikes a fine balance between freedom and guidance.

The aim in this context is to enable and support STEAM practices, often in combination with other, more traditional school typologies.

Space as an explorative tool
However, as the SENSE. model aspires to extend the current STEAM practice by putting the multi-sensory inquiry of students through creative exploration at its centre, it seems only natural that space as a sensory extension of the individuum can be activated as an epistemological tool. The active exploration of the environment will allow students to practice new forms of sensory enquiry, experiences and experiments. Soft or hard surfaces modulate sound in different ways, light reflects specific to materials, each place has a distinct smell, the tactility of touch matters, etc. Navigating a space with body extensions questions our common understanding of empirical analysis, using a space as a three "dimensional blackboard" to visualise a concept can create unexpected connections, etc. Thus, spaces can become a place of individual appropriation, with each individuum creating and communicating a unique sensory eco-system.

This approach reaches more into the experimental spectrum of the SENSE. methodology and might not always be appropriate for educational settings with a more pragmatic approach or limited acceptance of abstract sensory enquiry. However, as the SENSE. methodology incorporates feedbacking techniques to facilitate the reflection of the enquiry journey, the examination of the sensory impact of spaces – even for a «normal» activity - offers the opportunity to extend and enrich a more traditional STEAM pedagogy. A simple feedback discussion about how an environment might be adapted to the needs of the students can become an activating exercise in understanding the complexity of knowledge transfer, which is and should be an educational attainment in itself.

3.2.2. Social inclusion

Social inclusion is an important guiding principle in the SENSE. model. This guiding principle asks for a constant self-reflection process during the SENSE activities in each of the Steam Labs. It is important question who is involved in the planned activities and who is not involved. Afterwards, each Steam Lab should try to reflect on the possible reasons. It is also important to adopt an active listening attitude towards participants' during the development of the activities. The social inclusion guiding principle then ask when necessary to dynamically react and revise the planned activities in SENSE. STEAM Labs. Steam Lab would be ready to take an adaptive attitude along their efforts while having in mind that there is one-fits-all solution as the social and cultural context in each neighbourhood, city, region, or country across the consortia members may show very strong differences.

Social inclusion guiding principle is already part of the current discussions in several social spheres such as those discussed in previous sections. Museums, Cultural Centres and Public Libraries are indeed questioning themselves their own mission in relation to broad concept of Publics, in plural. This reflection affects not only the themes, the communication and the language used so far in these spaces, but it also involves the need to rethink fundamental aspects such as the notion of exhibition itself, to create satellite activities oriented to specific groups or even to build very narrow alliances with closest neighbourhood or directly with absent public in museums (such as young adults or stigmatized populations) to codesign activities that make them publicly visible.

Space and social relations that take place there are thus a fundamental aspect to consider when considering social inclusion. It is worth to mention the use and the presence in public spaces (and the non-use and the non-presence) of certain social groups. It is a very important context in relation to social inclusion and the same planned activities can be taken as a great opportunity to bring to specific groups and communities a louder voice in our societies. This might be relevant in for instance citizen science practices.

In the specific field of education, "inclusion is regarded as an extension of a comprehensive approach to education, in which children's rights and social justice are positioned at the forefront of educational thinking; one that goes beyond tolerance and compensating for pupils' perceived 'disabilities'" (Winzer, 2009, p. 183). Accordingly, inclusion encompasses the idea of recognising and appreciating diverse perspectives and contributions (Winzer, 2009).

Within SENSE, it is thus aimed to increase people's participation in the activities planned while the practices must highlight their competencies rather than deficits. Accessibility of content and format in materials and activities is also an important factor in taking an inclusive approach. Accessibility also needs to involve the use of plain language and the provision of content in a variety of formats. Here, inclusiveness is also aimed to enhance the participation of vulnerable and usually under-represented collectives in the activities.

The necessity of demonstrating informed consent (IC) of participants, is also a chance to further reflect on dimensions of inclusion. In other words, the IC is not only a tool to comply with GDPR regulations or requirements in scientific research. It can become an opportunity to further reflect on social inclusion in SENSE. activities. For example: The IC format must be offered in different formats to make its content fully understandable to anyone. IC can be dynamic covering specific activities and thus give flexibility to participants to step into the project or withdraw their participation. IC can be seen to show the responsibility of the project partners in the activities organised, to facilitate accountability in relation to activities' goals and project results and to build trust between organisers and participants. A good IC will also help to avoid any risk to participants which might particularly be relevant for groups of participants in a vulnerable situation.

Also, to monitor not only learning outcomes but also aspects related the mentioned elements above, it could be of interest to consider approximations such as the one adopted by the Theory of Planned Behavior (Ajzen, 1991) which assumes that the intention to remain engaged in the activities is best predicted by positive views, favourable opinions held by influential others (subjective norms), and by individual perceived ability (perceived behavioural control).

Finally, a special attention must be taken to Gender as discussed in the forthcoming section.

3.2.3. Gender inequalities in STEM: Challenging the glass ceiling

The fourth and fifth goals of the United Nations Sustainable Development Goals focus on gender equality and education. Achieving this requires closing the education gap for marginalised groups and all genders. Gender extends beyond women to include multiple identities such as men, gender fluid, genderqueer and non-binary individuals. In the SENSE project, our focus is on girls and women in STEM, with the aim of reducing the gender pay gap and increasing their economic stability.

While more women are entering STEM education, they remain underrepresented in high-paying roles (American Association of American Women, n.d.). Globally, women make up around 30% of researchers, but are even less represented in fields such as ICT (3%), mathematics and statistics (5%), and engineering, manufacturing and construction (8%) (World Economic Forum, 2020). Studies show that women in STEM publish less, receive less funding and progress less than their male counterparts (Casad et al., 2021). Pay inequality plagues women who venture into STEM careers. In 2020, the global gender gap score was 68.6%, with a remaining gap of 31.4% (Schwab et al., 2019). However, closing the gender gap requires addressing the factors that deter women from STEM careers.

Despite progress, negative stereotypes about girls' abilities in STEM persist (Hill, Corbett, & Rose, 2010). The misconception that boys excel in maths and science persists, discouraging girls. Cultural and gender stereotypes pose challenges to the pursuit of science and technology, influencing course choices as early as primary school (Hill, Corbett, & Rose, 2010).

While women's presence in STEM is increasing, barriers such as sexism and limited advancement remain (Casad et al., 2021). Women in male-dominated fields face discrimination and harassment, which is often worse for racial and ethnic minorities (Funk, 2018).
The lack of female role models contributes to the gender gap in STEM. Inclusivity requires effective communication strategies to promote a positive association between women and STEM from an early age. Learning materials should be adapted to include more female role models.

Intersectionality emphasises the interconnectedness of social identities, integrating gender with race, class and sexuality. Recognising these intersections shapes students' experiences and has implications for equitable change, rights, and accessibility. This holistic approach is in line with the aims of the SENSE project.

3.2.4. The contribution of arts and culture: Understanding the social value of heritage, museums and galleries

Significant changes have been noticed with respect both to the role of museums and culture in society and to that of the educational system in terms of intergenerational transmission as intra-generational peer learning expands. The decline of traditional types of authority in forms of learning as proceeded in sync with changes in the educational system and the sphere of traditional family. The same holds for relations between audiences and cultural institutions.

Traditionally, museums 'mission was to ensure access for all, expand their activities and promote the citizens' experience, whether it be on-site or remotely, for a large audience. More fundamentally, in relation to increased social inequalities, access for those who are most removed from cultural practices occupies nowadays a central place in European cultural policies. Regrettably, there is no alteration in the paradigm of cultural practices: cultural amateurs share the same overall socio-economic profile. The same is observed regarding uses of the internet and online cultural practices (DiMaggio and Hargittai, 2001; Evrard and Krebs, 2018).
Research is highlighting that the distance to museums is multifaceted: intellectual, physical, economical and/or socio-cultural.

For stakeholders, whatever they may be, it is very clear that explaining the museum and its collections is not for the benefit of museums themselves but to introduce to questions of artistic and cultural issues in order to help them feel better and better integrated in society. It is therefore crucial not to address any "instrumental" approach but to address users' aims linked to social, cognitive and sensory benefits, in other words, museums contribution to the creation or consolidation of a social and human capital.

From this perspective, the integration of arts and culture to educational programmes demonstrate that it is not the historical or artistic themes that matter most, but how history, archaeology, artworks, techniques (or even artists' lives) contribute in creating a sense that nurture people today (European Network of Cultural Centres, 2012).

Not to mention the need to create links between "high culture" and the variety of popular contemporary cultural genres (movies, comics, music...), an essential way to introduce a dialogue between classical art and those who find themselves far removed from culture. Thus, artists, cultural professionals and cultural facilities need to bring about a radical transformation: going beyond the traditional concepts of "accessing" cultural products or experiences that would merely be "incidental and occupational" (Kracman, 1996; Nagel, Damen and Haanstra, 2010).

Furthermore, cultural institutions are—still—struggling to demonstrate the systems of goods and values derived from cultural participation; this is due to disparities in research and methods, difficulties in extrapolating the results of studies, as well as cultural players' non-acceptance of "assessment" tools or the lack of resources devoted to the study and evaluation of public policies. These limitations are worth highlighting in order to understand the contemporary challenges facing museums and heritage when it comes to measuring their "public value," particularly in the area of learning and education.

The legitimation system of non-profit organisations (Greffe, Krebs and Pflieger, 2017) is still and mainly based on the production of a great many discourses and descriptions of the missions and effects of policies implemented (such as social impact, cohesion and cultural diversity). Assessments of "cultural democratisation" have now given way to lines of action and research devoted to how museums contribute to social inclusion, individual well-being or to the benefits of museums in terms of public health. But this "social" purpose of museums remains generic leading to a poor relation and the blind spot of public cultural policies, like a relatively marginal variable—especially in times of economic crisis, staff reductions and lower state support.

Yet some academic branches, such as the sociology of values (Heinich, 2006), have shown that this discipline can be used to describe and objectify the various registers of values associated with cultural participation. This approach is all the more relevant as it takes the viewpoint of users, their practices and representations, rather than the strict viewpoint of cultural organisations: a museum's "public value" is not one borne by Institution or Policy but is the result of an encounter between institutional values and individual (or collective) values. This academic movement highlights the existence of various "value registers" related to individual social and cultural practices: civic, ethical, juridical, functional, domestic, reputational, aesthetic or even "purificatory." In the case of museums and galleries, studies show that the dominant values users associate with cultural practices take the form of aesthetic (relating to beauty), aesthesic (value of sensory experience), hermeneutic (the interpretation of the practice in understanding and building individual identity) or even "purificatory" aspects in that a museum is perceived by its users as an area sheltered from the world (Anderson, 2004), where one is able to reflect on oneself, position oneself within a human history, and compare one's own identity to that of the past and that of other individuals. In other words, the artistic or cultural experience is a way of escaping from the contingency of the world, from its increased pace and conflicts, and of questioning them. Indeed, rarely do museumgoers, opera lovers or live performance aficionados promote "education" or learning as primary values when it comes to cultural participation.

Those different value registers pertaining to artistic or cultural participation vary in intensity and scope, ranging from those values that fall within "community realms" (shared widely by several individuals or social groups) and values that fall within "singularity realms" (shared by few individuals, without necessarily helping to create a sense of belonging to a wider group). Moreover, these various registers also fluctuate in time and space. It is therefore essential to study and take into account these value systems, particularly the way in which individuals and social groups draw upon and today enjoy experiences and "stories" whose source may lie in museums, galleries and their collections.

Understanding the museum's "public value" in today's world raises major challenges because contemporary societies are experiencing the fragmentation of conventional realms of belonging or recognition—in particular, "established" culture and its associated references (what used to be called "Humanities") are no longer transmitted or shared as a common core—. This shift and weakening are linked to the fact that they are no longer taught in educational systems or disseminated as a form of intergenerational, family heritage; but are also linked to people's new expectations in terms of culture and education; to the emergence of new cultural experiences and objects; and to new value registers specific to the younger generations.

Modern society has become much more divided in its opinions, representations, and values. The electoral processes, at local, national or international level, bear witness to the fact that it is becoming more difficult to obtain a political and civic consensus on societal issues concerning the coexistence of various social groups. At a time when divisions and tensions are growing more pronounced, between East and West, between developed and poor countries, between the upholders of a more open and tolerant society and those who advocate a return to the values of a past deemed unifying, current developments in the relationship between museums, galleries and their audiences now fall within a context of tensions that are becoming stronger instead of weaker. This helps explain the difficulty—and indeed the challenge—facing museums to act as *forums* rather than *temples,* providing legitimate venues for building areas of shared values belonging to the public, rather than their traditional role of normative settings for the display of cultures and histories considered dominant, unequivocal and hegemonic.

As regards education, museums have seen considerable changes, with extramural activities, participatory interpretation, technological solutions for fostering learning, partnerships with other cultural institutions and local players, and so forth. It is important today to consider the issue of the educational and social purpose of museums not only in terms of what they produce but also in terms of the values, or, more importantly, lack of values, for users.

The museum is one of the few places to offer areas that question the various realms of values connected to societies. Where will its focus for action lie tomorrow? Should the museum rally visitors around a culture "established" by states and regions? Should it help develop and foster a cultural community spanning several social groups? Should it encourage encounters between differentiated cultural forms and expressions? In a society in which individuals are particularly critical of their representative bodies, the challenge and the issue at stake lie in museums' ability to fulfil their social and democratic purpose, to build rich value spaces for people, and to promote the expression of a critical assessment of the world and its evolution, an essential contribution to the quality and ethics of the scientific curricula.

4. Entry points for SENSE.STEAM in policy and practice

There are several entry points that could introduce enriched STEAM education at different levels. In Deliverable D3.3 we presented the results of our stakeholder needs analysis, outlining the requirements of stakeholders and showing ways of accessibility to STEAM. In the next sections we undertake a further sequential step towards the implementation of STEAM education across Europe by looking into international and national policy documents.

4.1. International documents

The OECD has embarked on a journey to reinvigorate the education landscape through innovation. An example of this effort is the publication "OECD Future of Education and Skills 2030 - OECD Learning Compass 2030 - A Series of Concept Notes". This comprehensive compilation paints a vivid picture of what future education should embody, skilfully prepared to meet the challenges that lie ahead. In the quest to strengthen education and training systems with resilience and inclusiveness, the European Education Area (EEA) initiative stands as a beacon, fostering cooperation among the European Union's Member States. This collective effort, orchestrated by the Joint Research Centre on behalf of the European Commission, was launched in 2010 and over time has fostered a deeper understanding of essential components in education (Harlen, 2010).

At the European curriculum level, efforts are being made to develop a common reference framework for science education, inspired by the European Qualifications Framework (EQF). In "Principles and big ideas of science education", Wynne Harlen presents ten global principles of science education, of which principles 2, 3 and 6 provide entry points for STEAM educational elements such as learner-centredness, STEAM inquiry and sense making. A similar effort has been undertaken by the German association Mathematisch-naturwissenschaftlicher Unterricht (MNU) - Verband zur Förderung des MINT-Unterrichts. Based on a different structure, the Common Reference Framework for Science (GeRRN) advocates the teaching of relationships between the physical world, the learners' world, and the reflection on science as a cultural endeavour. These three propositions are also key to SENSE.STEAM and provide excellent grounds for future collaboration and joining forces for a renewal of STEM education in Europe.

Weaving the above elements together, we see several entry points for an enriched STEAM education. The EEA initiative, driven by the European Commission, serves as a collaborative platform to strengthen education systems. And as the OECD charts a course for educational innovation, we stand at the precipice of transformative pedagogy, ready to face the uncharted territory of the future. Common reference frameworks for science education in Europe can propose a widespread implementation of STEAM beyond national efforts.

4.2. Creating alliances with European STEAM initiatives

To identify existing STEAM initiatives is crucial to maximise impact and sustainability of STEAM education as a common effort on the European level. A detailed description of STEAM initiatives and how they relate to SENSE. can be found in deliverable 3.4, section 2.3. Here we will briefly outline where building alliances with existing or past initiatives can happen.

The potential for forging alliances between SENSE. and existing or past initiatives lies in creating relations of common practices identified in the projects reviewed. One exemplary practice is an inquiry-based, problem-solving approach that seeks to bridge science modules with everyday phenomena, facilitating students' connection to content and fostering a tangible understanding of 'why, what, how' questions. By embedding learning in real-life contexts, this strategy seamlessly integrates art and space, enriching the holistic framework of knowledge. The STORIES project is a case in point, where teams of students are tasked with developing inventive solutions to contemporary real-world challenges through the lens of science and engineering. At the same time, these teams are creating tangible models of their interventions and virtual representations of the solutions they have devised.

In addition to these these efforts, a broader perspective reveals that STEAM has progressively shaped modern pedagogies at the European level. Efforts towards inclusivity have provided educators with a solid foundation on which to build, and students with the means to truly engage while forging their individual identities. However, when examining projects from the last decade, a recurring observation emerges: The presence of art is not overwhelming. When it does appear, it tends to play a supplementary and peripheral role rather than being holistically integrated into knowledge creation and the teaching process. Often, art is used primarily to enhance the visual appeal of educational content designed to attract a diverse audience, rather than being seen as a central learning module essential for broadening cognitive horizons and enhancing engagement with science.

4.3. National curricula: STEAM and cross disciplinary approaches

Cross-disciplinarity, including STEAM in education, is becoming increasingly important to equip students with the skills they need to navigate complex and interconnected global issues. Schools may offer project-based learning opportunities that require students to draw on knowledge and skills from multiple disciplines to solve real-world problems. Many schools incorporate coding and robotics into their curricula and encourage students to think creatively and collaboratively to solve problems in these areas.
The inclusion of STEAM aspects in curricula is becoming more common among national governments. The table below provides concise illustrations of reform efforts in different countries, highlighting the diversity of initiatives being implemented across Europe. The selection of cases presented in Table X exemplifies a pervasive movement across Europe that emphasises greater integration and creativity in education, stemming from an acknowledgement of the limitations of conventional schooling in today's contexts .

Country	Initiative
Ireland	The Junior Cycle curriculum was reformed in 2015. The importance of the JC (early secondary school) examination has been reduced, teachers' freedom has increased, learners have more control over their learning, a Transition year for students before going to higher education have been introduced to explore their personal and potential future professional interests through interaction with the wider community. Positive results have been reached with integrating the SDGs in the classroom learning, with connections to wider society, (Brown *et al.*, 2023)
Norway	Integrated transdisciplinarity in the primary and secondary curricula on the national level, opening the doors for implementing sustainable and transformative learning in the schools (Utdannings-direktoratet, 2017).
Italy	The STEAM education movement has gained momentum in recent years, with a focus on incorporating the arts into STEM curricula in order to promote creative problem-solving and innovation (Cerini *et al.*, 2012; Comitato scientifico nazionale per l'attuazione delle Indicazioni nazionali e il miglioramento continuo dell'insegnamento, 2018).
UK	There is a growing emphasis on the importance of arts education in STEM subjects, with the government promoting initiatives that encourage schools to offer STEAM-based learning opportunities.

Table 1: Overview of cross-disciplinary and STEAM approaches in a sample of recently updated national curricula of European countries.

4.4. No curricula: Democratic education

Scholars and practitioners have criticised current curricula for undermining intrinsic motivation to learn, inhibiting critical thinking and inquiry, and teaching outdated content that is of no use in real life, while failing to provide the skills needed in the 21st century (Gray, 2013).
To counter the restrictions that curricula and school bureaucracy place on the creativity and performance of teachers and students, radical and successful moves have been made to abolish curricula altogether and instead give students control over what, how, when and from whom they learn, supported by facilitators who accompany them. An old and successful democratic school can be found in Sudburry Valley, which involves children in the day-to-day management of the school, including budgeting and staffing. Such an unstructured, creative and learner-centred approach automatically leads to subject integration and potentially to STEAM approaches. The learner is in charge of their own learning journey, which speaks to an important aspect of the SENSE approach of being learner-centred. Reverse ontology will emerge as an integral part of students choosing to understand a typical subject that is relevant to their everyday lives and understanding the need to explore the underlying theoretical knowledge.

Open Schooling
Open Schooling initiatives are actively promoted and supported by the European Commission, and aim to involve schools and learning in the wider community as active stakeholders to benefit learning and counteract science disengagement. "The Commission calls for the development of new science learning didactics based on an Open Schooling approach, in which science learning processes are strongly linked to students' participation in real scientific challenges in society and in real research and innovation circles". (Open Science Schooling, no date). They offer another entry point for SENSE, as they engage with stakeholders and community, potential for reverse ontology.

4.5. Further considerations supporting accessibility to STEAM education

In the realm of educational change, a key aspect of revolutionising established pathways in STEM and STEAM education is understanding stakeholder needs through careful analysis. But this is only the beginning. To truly reshape the landscape, we must also ensure accessibility and identify potential entry points for all stakeholders.

The call for a seamless fusion of cross-disciplinary STEM education and the infusion of STEAM methodologies into curricula has echoed through government corridors and academic debates since the 1990s. However, this quest has been met with formidable challenges, which have required innovative solutions to navigate.

The impact of falling PISA scores has triggered a transformative trend that threatens to overshadow creativity and innovation in education. The perceived need for standardised testing has inadvertently forced curricula to adopt a more regimented and performance-oriented stance. In doing so, it has inadvertently shackled the ingenuity of educators and institutions, leaving them with little room to improve teaching methods. This predicament, exacerbated by heavy administrative burdens, has hampered their daily efforts to shape the educational landscape. Many 21st century students are being educated using pedagogical practices that emerged during the 20th century and within a 19th century organisational framework Schleicher (2018).

The imperative to develop knowledge and skills for future-making, a constellation of creativity and imagination, empathy and affection, lifelong learning, and critical thinking, has gradually gained prominence among European policy makers, the Organisation for Economic Cooperation and Development (OECD) and the education community. However, the seamless integration of such skills into the tapestry of curricula and the learning continuum requires groundbreaking educational innovations and the metamorphosis of educational policies. The march towards this goal is likely to involve transdisciplinary co-construction and the convergence of subjects, a shift that the European Union has embarked upon through several pioneering initiatives.

4.5.1. Gender and social inclusion in curricula

Social cohesion is an important objective within the framework of the European Union. However, its integration into transnational and national curricula has been limited. While steps have been taken to increase gender neutrality and ethnic diversity in educational materials, as well as to present diverse role models and counter stereotypes, the inclusion of sexual minorities remains controversial. In the Nordic countries, efforts are being made to recognise non-traditional family structures, such as those with same-sex parents, and to address sexual diversity in sex education. However, in countries such as Poland and Georgia, resistance has hampered such efforts.

In addition, older textbooks often perpetuate conventional gender and racial stereotypes, reinforcing submissive and passive roles for girls and promoting bravery and activity for boys. These materials may depict mothers as caregivers and fathers as working outside the home, inadvertently reinforcing traditional gender roles. Another problematic portrayal is that of fathers 'helping' mothers to raise children, which fails to recognise that parenting is a shared responsibility that requires more than mere assistance. It's imperative to challenge these norms from early childhood education, which requires well-designed materials and informed educators. Notably, Georgia recently undertook a comprehensive gender analysis of its textbooks, resulting in more gender-neutral changes.

4.5.2. Louvre action-points for inclusion of stakeholders

A meta-analysis of the Musée du Louvre action-research programmes (Greffe and Krebs, 2021) found five key factors that foster quality and efficiency in projects that aim to develop societal and economic inclusion.

- The quality and strength of the relationships between the stakeholders of a given programme. This includes the concrete means and possible limitations of each partner, which must be identified from the beginning of a project.
- The accuracy of information and project communication. This is a key aspect in attracting and triggering participation among, in particular those whose backgrounds and skills *a priori* would not lead them be enticed by a programme. However, information is not enough: programmes managers are needed to actively search out for participants, accompany them, both physically and/or symbolically. For example, the classical selection bias[3] is an important limitation to participation and is often overlooked.
- Adapting themes, activities, and formats relevant to participants' concerns and experiences.
- Taking into account the issue of language. In particular, how to address and interact with citizens with a low literacy level overall or in the country's language. Special attention must be given to the different ways of addressing and interacting in terms of language, vocabulary level and/or social behaviours.
- Consideration of "extra-benefits": programmes objectives are too often focused on acquiring skills and knowledge structured along the lines of traditional academic learning. Social objectives as well as those concerning intellectual, affective or sensorial well-being and social skills all deserve a place as important as those given to acquiring knowledge.

5. Conclusions

Forging a transformed European landscape through SENSE.STEAM
In the journey to transform education for the betterment of learners and society, the SENSE.STEAM methodology emerges as a guiding light, illuminating the path towards a more inclusive, effective, and impactful educational paradigm. As we draw the curtain on this document we reflect on the intricate tapestry of insights, methodologies and considerations that have been woven together to lay the theoretical foundation for the projects' final ambition, The New European Roadmap for STEAM Education.

A comprehensive evolution of STEAM education was presented in section 2. Exploring the state of the art in STEAM education has revealed a dynamic field that goes beyond

[3] Selection bias also importantly includes issues of self-selection bias. The conscious or unconscious principles of self-exclusion from programmes are numerus, including intimidation, lack of interest, feeling incompetent, and more.

the mere merging of disciplines. It is a transformative approach that blends artistic creativity with scientific inquiry, fostering innovation and critical thinking. The literature review highlights the importance of balancing artistic infusion and scientific exploration, recognising the role of both in fostering holistic learning experiences.

STEAM education isn't just about imparting knowledge; it's about learning from past endavours, achievements and failure. It is the catalyst for future-making, a realm where learners are empowered to imagine and create the world they want to live in. Understanding the underlying assumptions of traditional STEM approaches such as inquiry-based learning and the impact of the primacy of the scientific model on how we shape education highlights the need to embrace a wider range of perspectives in order to cultivate well-rounded and forward-thinking individuals.

How does SENSE. propose to pioneer pathways to transformative learning in STEAM? At the heart of the SENSE.STEAM approach are the key components that move education in a learner-centred, reflective and collaborative direction. By renewing the relationship between art and science through STEAM inquiry, learners are equipped with the tools to explore the uncharted territories of knowledge. Encouraging citizen participation in science and the arts not only democratises learning, but also creates a platform for community engagement and societal progress.

Embedded in the SENSE.STEAM methodology are core pathways that address critical challenges and open doors to unexplored potential. The impact of environment and space, the pursuit of social inclusion, the reduction of gender inequalities and the recognition of the social value of arts and culture are examples of the comprehensive approach taken by SENSE.STEAM. By embracing these pathways, we are creating an inclusive educational ecosystem that thrives on diversity and collaboration.

From theory to action: Programmatic Entry Points.
This document is not just in the realm of ideas or academic discourse. It is for taking action and becoming an advocate of STEAM. Therefore, we identify strategic entry points for integrating SENSE.STEAM into policy and practice (more on that in D.2.7, our first policy brief). By drawing on international documents, forging alliances with existing initiatives, and addressing national curricula we build bridges to a future where STEAM education is accessible to all.

Finally, this document is a testament to the collective efforts of educators, policymakers and visionaries dedicated to the advancement of education. The SENSE.STEAM methodology, its educational components, pathways and entry points are not just words on paper; they are the building blocks of a brighter, more inclusive and innovative European educational landscape. Let this document be the compass that guides us towards a transformed educational journey, where learners are empowered to shape their future and society thrives as a result.

6. References

Abd-El-Khalick, F. *et al.* (2004) 'Inquiry in science education: International perspectives', *Science Education*, 88, pp. 397–419. Available at: https://doi.org/10.1002/sce.10118.

.able Journal - About (no date) *.able Journal*. Available at: https://able-journal.org/about/ (Accessed: 28 August 2023).

Ajzen, I. (1991) 'The theory of planned behavior', *Organizational behavior and human decision processes*, 50(2), pp. 179–211.

Anderson, E. (2004) 'The Cosmopolitan Canopy', *The ANNALS of the American Academy of Political and Social Science*, 595(1), pp. 14–31. Available at: https://doi.org/10.1177/0002716204266833.

Barbican (2022) *Barbican Box Learning Resource | Barbican*. Available at: https://www.barbican.org.uk/barbican-box-learning-resource (Accessed: 29 August 2023).

Barrett, P. *et al.* (2013) 'A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning', *Building and Environment*, 59, pp. 678–689. Available at: https://doi.org/10.1016/j.buildenv.2012.09.016.

Biesta, G. (2018) 'What if? Art education beyond expression and creativity", in C. Naughton, G. Biesta, and D.R. Cole (eds) *Art, Artists and Pedagogy*. Routledge, pp. 11–21.

Breiner, J.M. *et al.* (2012) 'What Is STEM? A Discussion About Conceptions of STEM in Education and Partnerships', *School Science and Mathematics*, 112, pp. 3–11.

Brophy, S. *et al.* (2008) 'Advancing Engineering Education in P-12 Classrooms', *Journal of Engineering Education*, 97(3), pp. 369–387.

Brown, S. *et al.* (2023) 'The role of teacher agency in using GIS to teach sustainability: an evaluation of a lower secondary school story mapping GIS initiative in Ireland', *International Research in Geographical and Environmental Education*, 0(0), pp. 1–16. Available at: https://doi.org/10.1080/10382046.2023.2214044.

Burnard, P. *et al.* (eds) (2019) *Why Science and Art Creativities Matter: (Re-)Configuring STEAM for Future-Making Education*. Brill. Available at: https://brill.com/view/title/54614 (Accessed: 26 September 2022).

Burnard, P., Colucci-Gray, L. and Cooke, C. (2022) 'Transdisciplinarity: Re-Visioning How Sciences and Arts Together Can Enact Democratizing Creative Educational Experiences', *Review of Research in Education*, 46(1), pp. 166–197.

Burnard, P., Colucci-Gray, L. and Sinha, P. (2021) 'Transdisciplinarity: letting arts and science teach together', *Curriculum Perspectives*, 41(1), pp. 113–118. Available at: https://doi.org/10.1007/s41297-020-00128-y.

Buttimer, A. (1976) 'Grasping the dynamism of lifeworld', *Annals of the association of American geographers*, 66(2), pp. 277–292.

Catterall, J.S., Dumais, S.A. and Hampden-Thompson, G. (2012) *The arts and achievement in at-risk youth: Findings from four longitudinal studies (No*. Research Report #55). National Endowment for the Arts.

Cerini, G. *et al.* (2012) *Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo d'istruzione*. Available at:

https://www.miur.gov.it/documents/20182/51310/DM+254_2012.pdf (Accessed: 29 August 2023).
Colucci-Gray, L. *et al.* (2013) 'Science education for sustainability, epistemological reflections and educational practices: from natural sciences to trans-disciplinarity', *Cultural Studies of Science Education*, 8(1), pp. 127–183.
Colucci-Gray, L. *et al.* (2019) 'A Critical Review of STEAM (Science, Technology, Engineering, Arts, and Mathematics)', in Colucci-Gray, L. et al., *Oxford Research Encyclopedia of Education*. Oxford University Press. Available at: https://doi.org/10.1093/acrefore/9780190264093.013.398.
Comitato scientifico nazionale per l'attuazione delle Indicazioni nazionali e il miglioramento continuo dell'insegnamento (2018) *Indicazioni Nazionali e Nuovi Scenari*. Available at: https://www.miur.gov.it/documents/20182/0/Indicazioni+nazionali+e+nuovi+scenari/3234ab16-1f1d-4f34-99a3-319d892a40f2 (Accessed: 29 August 2023).
Cook, K. *et al.* (2020) 'Development of elementary teachers' science, technology, engineering, arts, and mathematics planning practices', *School Science and Mathematics*, 120(4), pp. 197–208.
Costantino, T. (2018) 'STEAM by another name: Transdisciplinary practice in art and design education', *Arts Education Policy Review*, 119(2), pp. 100–106.
Dahlin, B. (2003) 'The Ontological Reversal: A figure of thought of importance for science education', *Scandinavian Journal of Educational Research*, 47:1, pp. 77–88. Available at: https://doi.org/10.1080/00313830308606.
Dijksterhuis, E.J. (1961) *The mechanization of the world picture*. JSTOR.
Dillon, J. and Watts, M. (2023) *Debates in Science Education*. Edited by Eds). London: Routledge.
DiMaggio, P. and Hargittai, E. (2001) 'From the 'digital divide'to "digital inequality": Studying Internet use as penetration increases', *Princeton: Center for Arts and Cultural Policy Studies, Woodrow Wilson School, Princeton University*, 4(1), pp. 4–2.
Eisner, E. (2001) 'From episteme to phronesis to artistry in the study and improvement of teaching', *Teaching and Teacher Education*, 18, pp. 375–385.
Eisner, E.W. (1991) 'What Really Counts in Schools.', *Educational Leadership*, 48(5), pp. 10–11.
Eisner, E.W. (2002) 'What Can Education Learn from the Arts About the Practice of Education?.', *Journal of curriculum and supervision*, 18(1), pp. 4–16.
European Network of Cultural Centres (2012) *A report on policies and good practices in the public arts and in cultural institutions – to promote better acces to and wider participation in culture*. Available at: https://encc.eu/resources/database/report-policies-and-good-practices-public-arts-and-cultural-institutions-promote (Accessed: 11 August 2023).
Evrard, Y. and Krebs, A. (2018) 'The authenticity of the museum experience in the digital age: the case of the Louvre', *Journal of Cultural Economics*, 42, pp. 353–363.
Fayard, A.-L. and Weeks, J. (2014) 'Affordances for practice', *Information and Organization*, 24(4), pp. 236–249. Available at: https://doi.org/10.1016/j.infoandorg.2014.10.001.

Gibson, J.J. (2015) *The ecological approach to visual perception*. Classic edition. New York: Psychology Press.
Greene, M. (2001) *Variations on a Blue Guitar: The Lincoln Center Institute Lectures on Aesthetic Education*. TC Press.
Greffe, X. and Krebs, A. (2021) *Poétique du patrimoine: entre Narcisse et Ulysse*. HAL.
Greffe, X., Krebs, A. and Pflieger, S. (2017) 'The future of the museum in the twenty-first century: recent clues from France', *Museum Management and Curatorship*, 32(4), pp. 319–334.
Guldi, J. (no date) *What is the Spatial Turn? · Spatial Humanities*. Available at: https://spatial.scholarslab.org/spatial-turn/what-is-the-spatial-turn/ (Accessed: 19 April 2023).
Hagendijk, T. *et al.* (2020) 'Reworking Recipes and Experiments in the Classroom', in S. Dupre et al. (eds) *Maartje Stols-Witlox, Reconstruction, Replication and Re-enactment in the humanities and social sciences*. Amsterdam University Press.
Harlen, W. (2010) *Principles and big ideas of science education*. Association for Science Education.
Harvey, C.W. (1989) 'Husserl's phenomenology and the foundations of natural science'.
Hattie, J. and Timperley, H. (2007) 'The power of feedback', *Review of educational research*, 77(1), pp. 81–112.
Heinich, N. (2006) 'La sociologie à l'épreuve des valeurs 1', *Cahiers internationaux de sociologie*, (2), pp. 287–315.
Hillier, B. and Hanson, J. (1989) *The social logic of space*. Cambridge university press.
Hubbard, P. and Kitchin, R. (eds) (2011) *Key thinkers on space and place*. 2nd ed. Los Angeles, [Calif.]: Sage.
Ingold, T. (2019) 'What Knowledge Do We Need for Future-Making Education?', in *Why Science and Art Creativities Matter*. Brill, pp. 432–439. Available at: https://doi.org/10.1163/9789004421585_024.
Johnson, M. (2007) *The meaning of the body. Aesthetics of human understanding*. The University of Chicago Press.
Kavanagh, A. (2018) 'Studying the Musical Ecology of Place in Irish Towns through Deep Mapping', *NPPSH Reflections*, 2, pp. 22–32.
Kavanagh, A. (2020a) 'Researching Music- and Place-Making Through Engaged Practice: Becoming a Musicking-Geographer', *Geographical Review*, 110(1–2), pp. 92–103. Available at: https://doi.org/10.1111/gere.12335.
Kavanagh, A. (2020b) 'Researching music-and place-making through engaged practice: becoming a musicking-geographer', *Geographical Review*, 110(1–2), pp. 92–103.
Kracman, K. (1996) 'The effect of school-based arts instruction on attendance at museums and the performing arts', *Poetics*, 24(2–4), pp. 203–218.
Liao, C. (2016) 'From Interdisciplinary to Transdisciplinary: An Arts-Integrated Approach to STEAM Education', *https://www.tandfonline.com/doi/full/10.1080/00043125.2016.1224873*, pp. 44–49. Available at: https://doi.org/10.1080/00043125.2016.1224873.
Lobo, L., Heras-Escribano, M. and Travieso, D. (2018) 'The History and Philosophy of Ecological Psychology', *Frontiers in Psychology*, 9. Available at:

https://www.frontiersin.org/articles/10.3389/fpsyg.2018.02228 (Accessed: 17 April 2023).

‘Making and Knowing Project – Intersections of Craft Making and Scientific Knowing’ (no date). Available at: https://www.makingandknowing.org/ (Accessed: 28 August 2023).

Marshall, J. (2010) ‘Five ways to integrate: Using strategies from contemporary art’, *Art Education*, 65(3), pp. 13–19.

Massey, D. (1994) *Space, Place and Gender*. University of Minnesota Press.

Massey, D. (2008) *A global sense of place*. Routledge.

Mazzucato, M. (2018) *Mission-oriented research & innovation in the European: a problem-solving approach to fuel innovation-led growth, Publications Office of the European Union: Luxembourg.* Report. Luxembourg: Publications Office of the European Union. Available at: https://publications.europa.eu/en/publication-detail/-/publication/5b2811d1-16be-11e8-9253-01aa75ed71a1/language-en (Accessed: 29 August 2023).

Meyers-Levy, J. and Zhu, R. (2007) ‘The influence of ceiling height: The effect of priming on the type of processing that people use’, *Journal of consumer research*, 34(2), pp. 174–186.

Müller, M. and Schumann, S. (2021) *Technische Bildung: Stimmen aus Forschung, Lehre und Praxis*. Waxmann Verlag.

Nagel, I., Damen, M.-L. and Haanstra, F. (2010) ‘The arts course CKV1 and cultural participation in the Netherlands’, *Poetics*, 38(4), pp. 365–385.

Nicolescu, B. (2012) *Transdisciplinarity and Sustainability*. Edited by Ed). The ATLAS publishing.

Norman, D. (2013) *The Design of Everyday Things: Revised and Expanded Edition*. Revised edition. New York, New York: Basic Books.

Osborne, J. (1990) ‘Sacred cows in physics-towards a redefinition of physics education’, *Physics Education*, 25(4), p. 189.

Østergaard, E. (2017) ‘Earth at Rest. Aesthetic Experience and Students’ Grounding in Science Education’, *Science & Education*, 26, pp. 557–582.

Perignat, E. and Katz-Buonincontro, J. (2019) ‘STEAM in practice and research: An integrative literature review’, *Thinking Skills and Creativity*, 31, pp. 31–43. Available at: https://doi.org/10.1016/j.tsc.2018.10.002.

Quigley, C.F., Herro, D. and Jamil, F.M. (2017) ‘Developing a conceptual model of STEAM teaching practices’, *School Science and Mathematics*, 117(1–2), pp. 1–12.

Roth, W.-M. (2015) ‘Enracinement or the earth, the originary ark, does not move: on the phenomenological (historical and ontogenetic) origin of common and scientific sense and the genetic method of teaching (for) understanding’, *Cultural Studies of Science Education*, 10(2), pp. 469–494.

Roth, W.-M., McGinn, M.K. and Bowen, G.M. (1998) ‘How prepared are preservice teachers to teach scientific inquiry? Levels of performance in scientific representation practices’, *Journal of science teacher education*, 9(1), pp. 25–48.

Sailer, K. (2018) ‘Corridors, Classrooms, Classification – The impact of school layout on pedagogy and social behaviours’, p. 20.

Sailer, K. (2021) ‘Routine action networks: An architectural study of spatial layouts and performativity in outpatient clinics’, *Social Networks* [Preprint]. Available at: https://doi.org/10.1016/j.socnet.2021.12.004.
Schleicher, A. (2018) ‘Educating learners for their future, not our past’, *ECNU Review of Education*, 1(1), pp. 58–75.
Schulze Heuling, D. and Schulze Heuling, L. (2023) ‘Naturwissenschaftliche Bildung’, in *Bildung als Herausforderung*, pp. 125–134.
Schulze Heuling, L. (2017) ‘Praxisforschung durch kunstbasierte Methoden’, in *Forschendes Lernen an der Europa-Universität Flensburg*, p. 63.
Schulze Heuling, L. (2021) ‘Promoting student interest in science: The impact of a science theatre project’, *LUMAT: International Journal on Math, Science and Technology Education*, 9(2), pp. 63–81.
Shute, V.J. (2008) ‘Focus on formative feedback’, *Review of educational research*, 78(1), pp. 153–189.
Smith, C. (2017) ‘The Influence of Hierarchy and Layout Geometry in the Design of Learning Spaces’, *Journal of Learning Spaces*, 6(3), pp. 59–65.
Tanner, C.K. (2000) ‘The influence of school architecture on academic achievement’, *Journal of Educational Administration*, 38(4), pp. 309–330. Available at: https://doi.org/10.1108/09578230010373598.
Tobia, V. *et al.* (2022) ‘The influence of classroom seating arrangement on children’s cognitive processes in primary school: the role of individual variables’, *Current Psychology*, 41(9), pp. 6522–6533. Available at: https://doi.org/10.1007/s12144-020-01154-9.
Torres Gomez, J. *et al.* (2021) ‘Teaching Differently: The Digital Signal Processing of Multimedia Content Through the Use of Liberal Arts’, *IEEE Signal Processing Magazine*, 38(3), pp. 94-104,.
Torres, J.T., Strong, Z.H. and Adesope, O.O. (2020) ‘Reflection through assessment: A systematic narrative review of teacher feedback and student self-perception’, *Studies in Educational Evaluation*, 64, p. 100814.
Trotman, A. (2017) *Why don’t European girls like science or technology?*, *Microsoft News Centre Europe*. Available at: https://news.microsoft.com/europe/features/dont-european-girls-like-science-technology/ (Accessed: 10 August 2023).
Tuan, Y.-F. (1977) *Space and place: The perspective of experience*. U of Minnesota Press.
Tuan, Y.-F. (1979) *Space and place: humanistic perspective*. Springer.
Utdannings-direktoratet (2017) *Læreplan i naturfag (NAT01-04)*. Available at: https://www.udir.no/lk20/nat01-04?lang=nob (Accessed: 29 August 2023).
Van Manen, M. (2023) *Phenomenology of practice: Meaning-giving methods in phenomenological research and writing*. Taylor & Francis.
Vanderstraeten, R. (2002) ‘Dewey’s transactional constructivism’, *Journal of Philosophy of Education*, 36(2), pp. 233–246.
Villarreal Arroyo, Y.P., Peñabaena-Niebles, R. and Berdugo Correa, C. (2023) ‘Influence of environmental conditions on students’ learning processes: A systematic review’, *Building and Environment*, 231, p. 110051. Available at: https://doi.org/10.1016/j.buildenv.2023.110051.

Winzer, M.A. (2009) *From integration to inclusion: a history of special education in the 20th century*. Washington, DC: Gallaudet University Press.

7. Appendix

Annex 1: Historical perspectives on the interconnection between theatre and science

Both inside and outside the realm of artistic research, performance-based practices are increasingly mobilised as methodological tools by several disciplines ranging from the history of science and technology, anthropology, art history, or musicology in order to emphasise the embodied and sensitive dimension of knowledge. This set of approaches can take different directions depending on the objectives of the research, its conceptual frameworks, its devices, and its contexts of application. Performance-related methods under the label of the Re-terminology (Reconstruction, Re-enactement, Replication, Reproduction and Re-working), "are playing an increasing prominent role in research into historical production processes, material and bodily knowledge, and sensory skills, and in forms of education and public engagement in classrooms and museums[13]" (Kursell et al., p. 9). Disciplines such 'experimental history of science' (a termed coined by historian of science H. Otto Sibum in the 1990s) which is closely intertwined with science education, pointed to an interdisciplinary awareness of performative methods which would serve to unlock tacit skill and knowledge of experimental scientific practices. For example, Sibum (2020) reconstructed past scientific experiments, making replicas of historical instruments and using them in a performance context. The notion of body techniques in the sense given by French ethnographer Marcel Mauss in 1934, is at the base of what Sibum calls the knowing body. Within this experimental methodological approach, the role of human body and, in particular the place of the scientist's body, along with the notion of gestural knowledge (Sibum, 1995) – understood as the set of skills and forms of mastery developed in real-time performances – are central to understand the history of the production of scientific knowledge. This gestural knowledge is a practical knowledge of a dynamic nature which can only be communicated and transmitted through active participation.

The *mise en scène* of sciences (and of techniques) is part of a long tradition that is constantly being rethought and renewed. The history of modern science is linked to the uses of the practices and techniques of fiction and visualisation specific to literature and the arts. Since its emergence in the 17th century, modern science in its association with the concepts of proof, experimentation and public demonstration is also closely connected to the history of theatre and spectacular devices (Aït-Touati, 2022). Based on these approaches, the stage-based experiments conceived by Frédérique Aït-Touati and Bruno Latour[4] were born of a common conviction of a

[4] Frédérique Aït-Touati and Bruno Latour developed many theatrical collaborations in projects such as Inside (2016), Moving Earths (2019) or Viral (2021).

necessary alliance between science and art, between knowledge and its forms of expression. The configurations between theatrical methodologies, visualisation techniques and processes of dissemination of scientific knowledge are multiple, ranging from very didactic approaches to more radical experimentation. Within this dynamic, it is worth mentioning the implementation of projects for the construction of theatrical spaces specifically dedicated to interdisciplinary collaboration within the framework of scientific university institutions, as is the case of the historical *Tieranatomisches Theater* opened at Humboldt University or the *Scène de Recherche*, a theatre operating as a platform for research-creation built within the Université Paris-Saclay.

The exhibition format, whether inside or outside the museum, and its display strategies, seems to be a fundamental device for constructing spaces of exchange and dialogue oriented towards the co-production of multiple types of knowledge. The series of exhibitions conceived by Bruno Latour and Peter Weibel at the Centre for Art and Media (ZKM) in Karlsruhe since the 2000s are representative of these approaches[5]. In the framework of research-creation approaches, the exhibition expands its functions and can become a place of research production, beyond a mere format for presenting results at the end of a process. The exhibition develops as a platform for negotiation and evaluation of a research process involving the public. Thus, within the expanded field of curating, exhibitions can be understood as research and the curatorial as a specific system of knowledge production in relation with other forms of research. In this sense a curatorial project – including its most dominant form, the exhibition – should not only be considered as a form of mediation of research but as a site for carrying out this research, as a place for enacted research (Sheikh, 2013). Heering and Schulze Heuling (2020) contextualise the relationship between art and science knowledge creation for science education in the thematic issue “Physik auf der Bühne.”

Furthermore, these ideas are in line with the contemporary discourse fostered by the recent conference series on Theatre about Science, to be held in Coimbra (Portugal) in 2021 and 2023, which highlights the continued exploration of performative methodologies at the intersection of scientific knowledge and artistic expression.

References

Aït-Touati, F. (2021) ‘Pour un théâtre-laboratoire: retour d’expériences’, *Écrire l’histoire. Histoire, Littérature, Esthétique*, (20–21), pp. 257–260.
Heering, P. and Schulze Heuling, L. (2020) *Inszenierungen (in) der Physik - Ein Plädoyer für mehr „Drama“ im Physikunterricht*. Available at: https://www.friedrich-

[5] Bruno Latour and Peter Weibel curated a series of Gedankeausstellung, roughly translated as “Though Exhibition, such as Iconoclash: beyond the image wars in science, religion, and art (2002), Making Things Public. Atmospheres of Democracy (2005), Reset Modernity (2016) or Critical Zones (2020-22). Bruno Latour's latest exhibition was held at the Centre Pompidou-Metz, Toi et moi on ne vit pas sur la même planète in 2022.

verlag.de/friedrich-plus/sekundarstufe/physik/unterricht-lernen/inszenierungen-in-der-physik-3018 (Accessed: 30 August 2023).
Kursell, J. *et al.* (2020) *Reconstruction, replication and re-enactment in the humanities and social sciences*. Amsterdam University Press.
Sheikh, S. (2013) ‘Towards the exhibition as research’.
Sibum, H.O. (1995) ‘Working experiments: a history of gestural knowledge’, *The Cambridge Review*, 116(2325), pp. 25–37.
Sibum, H.O. (2020) ‘10. Science and the Knowing Body: Making Sense of Embodied Knowledge in Scientific Experiment’, *Reconstruction, Replication and Re-enactment in the Humanities and Social Sciences*, p. 275.

Annex 2: Delphi study: Methodological considerations and Delphi consortium

Delphi studies, a qualitative research approach based on expert consensus, have emerged as a key method in educational research. Named after the oracle of Delphi in ancient Greece, this method engages a panel of experts through iterative rounds of surveys or questionnaires with the aim of achieving convergence of opinion on relevant educational issues. This scholarly exposition explores the distinctive features, procedural intricacies, applications, and challenges that characterize Delphi studies in the context of educational research.

Characteristics and procedures:
Delphi studies are characterised by a systematic methodology that seeks to harness the collective wisdom of experts to address uncertainties and explore multifaceted educational phenomena. The process typically involves several rounds of data collection and feedback. In the first phase, panellists provide open-ended responses to a carefully crafted set of questions, offering insights into the educational issue under study. These responses are then synthesised and anonymised before being presented back to the experts in subsequent rounds, where they are encouraged to refine and validate their views based on the insights shared by their peers. This iterative process facilitates the gradual convergence of opinions and the identification of prevailing themes or patterns.

Delphi studies with a focus on educational research hold great promise for a range of educational contexts. Within this field, experts can collaborate to provide insights into impending shifts in pedagogical paradigms, the integration of technology in the classroom, curriculum development, and the formulation of educational policy. In addition, Delphi studies provide a dynamic platform for building consensus in areas where empirical data may be scarce, such as predicting the future of distance learning, identifying key competencies for 21st century learners, and addressing the challenges of cultural diversity in education.

The Delphi study of the SENSE.STEAM methodology builds first on the expert feedback we received during the STEAM DNA workshop in Bergen (Nov 2022). In a second step, we collected a total of feedback from 28 experts in two rounds between July and August 2023. The first Delphi session was digital and involved Andrè Lepecki and Peter Heering as advisory board members. The second round of expert feedback was a digital meeting on 06.07.2023 including Bojana Kunst, Güliz K. Semiz and Trine Ørbæk. The last collection of expert feedback took place as physical meeting on 17.08.2023 in Edinburgh with feedback provided by Ramsey Affifi, Anthony Weston, Anne Pirrie, Julia Skilton, Elisabeth Angerer, ML White, Bashaer Alotaibi, Isobel Finnie, Nick Hood, Aline Nardo, Robbie Nicol, David Clarke, Shari Sabeti, Pamela Burnard, Donald Gray, Tim Ingold, Kirsten Darling-Mcquistan, Stephen Day, Jonathan Hancock, Joris Vlieghe, Lewis Stockwell, Kwesi Amoak and Carolyn Cooke. The full list of experts and very brief description of expertise can be found below.

Prof. Andrè Lepecki, Critical dance studies and performance theory, New York University
Prof. Peter Heering, Physics and its didactics and history, Europa-Universität Flensburg
Prof. Bojana Kunst, Dance studies, Justus-Liebig-University Gießen
Dr Güliz K. Semiz, Sustainability education and outdoor learning, climate change education, Agri Ibrahim Çeçen Üniversitesi
Prof. Trine Ørbæk, Pedagogy, teacher education, phenomenology, choreography, Universitetet i Sørøst-Norge
Dr Ramsey Affifi, Science and Environmental Philosophy Education, University of Edinburgh
Dr Anthony Weston, Philosophy, education, environmentalism, Elon University
Dr Anne Pirrie, Education, University of the West of Scotland
Julia Skilton, Climate Change Education, University of Edinburgh
Elisabeth Angerer, Philosophy of education, environmentalism, University of Edinburgh
Dr ML White, Transformative learning and teaching, University of Edinburgh
Dr Bashaer Alotaibi, STEAM in early childhood, University of Edinburgh
Isobel Finnie, Art education, University of Edinburgh
Dr Nick Hood, Physics education, University of Edinburgh
Dr Aline Nardo, Philosophy of education, University of Edinburgh
Prof. Robbie Nicol, Place-based education, University of Edinburgh
Dr David Clarke, Biomolecular mas spectrometry, University of Edinburgh
Dr Shari Sabeti, Arts and Humanities Education, University of Edinburgh
Prof. Pamela Burnard, Arts, creativities and educations, University of Cambridge
Prof. Donald Gray, Teacher education, science, society and sustainability, University of Aberdeen
Prof. Tim Ingold, Anthropology, philosophy, University of Aberdeen
Dr Kirsten Darling-Mcquistan, Early years education, University of Aberdeen
Dr Stephen Day, Teacher education and science education, University of the West of Scotland
Jonathan Hancock, STEAM education, University of Edinburgh
Prof. Joris Vlieghe, Philosophy of education, culture and society, Katholieke Universiteit Leuven
Lewis Stockwell, Philosophy of education, University of Edinburgh
Kwesi Amoak, Anthropology of education, University of Ghana
Dr Carolyn Cooke, Music education and transdisciplinary learning, Open University