STEAM Approaches Handbook

Erasmus+

BIRMINGHAM CITY
University

Contributors

Editors

Kathryn Burns; Tom Cahill-Jones; Claudia Carter; Charmaine Stint; Laura Veart
Birmingham City University

Acknowledgements

The Editors would like to thank all participants of the STEAM INC. project partnership for their contributions:

Heather Barnett
Central Saint Martins

Jo Berry
Birmingham City University

Natasa Brouwer-Zupancic
University of Amsterdam

Nathan Cohen
Central Saint Martins

Alessandro Columbano
Birmingham City University

Jaana Brinck
Aalto University

Eva Durall
Aalto University

Robert Fischer
TU Dresden

Henriette Greulich
TU Dresden

Adrian Holme
Central Saint Martins

Mairead Hurley
Science Gallery at
Trinity College Dublin

Teemu Leinonen
Aalto University

Daniel Lordick
TU Dresden

Frank Nack
University of Amsterdam

Annette Naudin
Birmingham City University

Andrew Newman
Ars Electronica

Lisa Nickolaus
TU Dresden

André Nusselder
University of Amsterdam

Jacobijn Sandberg
University of Amsterdam

Jean O'Shea
Science Gallery at
Trinity College Dublin

Shaun Ussher
Science Gallery at
Trinity College Dublin

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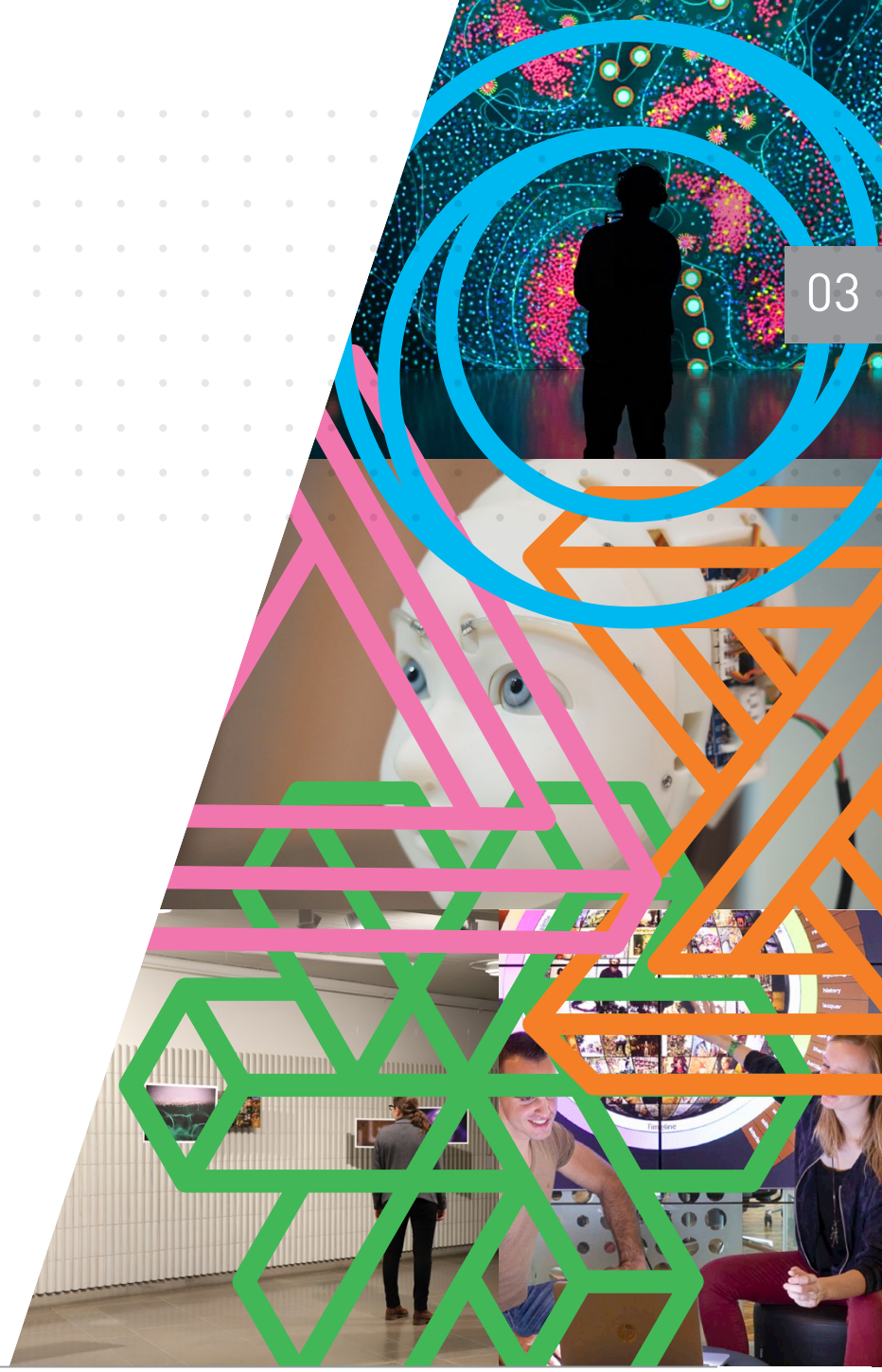
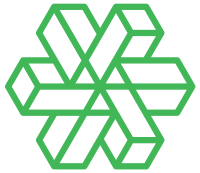


The colours, shapes and ethos that symbolise our STEAM approaches

BEHAVIOUR

the way that an individual or group acts, particularly in relation to collaboration.

CULTURES



the collective values, beliefs and modes of operation which are advocated by STEAM practitioners.

ENGAGEMENT

processes which promote open involvement and stimulate wide interest.

SPACE

the places from which STEAM activity is delivered.

Introduction

Welcome to the STEAM Approaches Handbook. This is the first of three main outputs of the STEAM Innovation and Curriculum project (STEAM.INC) which is funded through Erasmus+.

For those unfamiliar with the term, STEAM is an acronym for Sciences, Technology, Engineering, Arts and Mathematics. For the STEAM.INC project, Arts encompasses artistic, cultural and creative practices, including design. Also the Sciences includes, not only the traditional natural sciences, but also more contemporary topics such as social and environmental sciences. Overall, among other benefits, STEAM is increasingly viewed as a means of equipping the workers of the future with an interdisciplinary understanding that embraces a creative approach and innovative skills.

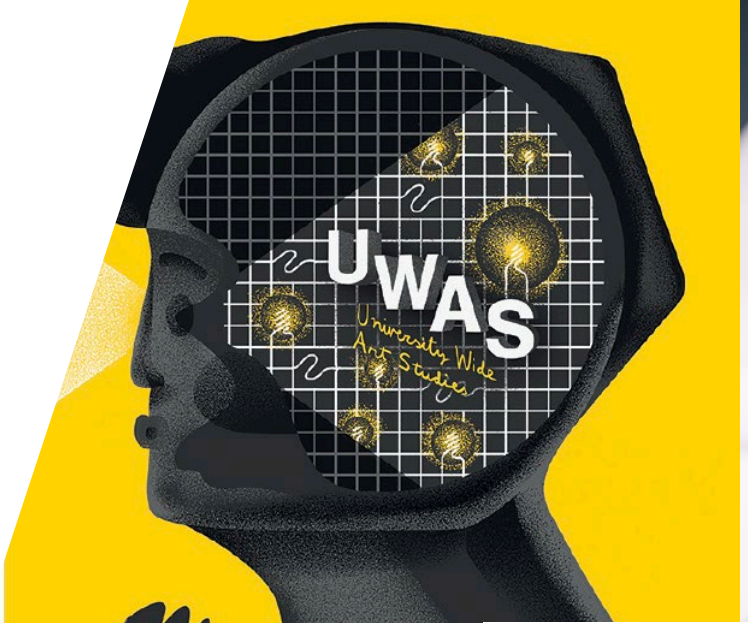
The STEAM.INC project runs from October 2019 to January 2023 and involves seven partners from across Europe, all of whom have developed STEAM endeavours to varying degrees. The project has three objectives:

1. **Identify** points of intersection across current European Higher Education STEAM approaches and develop a collaborative definition of Higher Education STEAM.

2. **Produce** methodologies for the implementation of STEAM thinking in Higher Education, policy and engagement.

3. **Create** an evaluation framework for measuring the effectiveness of STEAM processes in Higher Education Institutions and Higher Education partner organisations.

Introduction



This handbook addresses the first objective with an emphasis on how STEAM applies in Higher Education. For the project partnership, STEAM in Higher Education includes the customary teaching and curriculum as well as academic research. It also incorporates internal Higher Education policies and governance as well as external engagement with stakeholders and the public. These often become mutually supportive. For example, a university that embraces STEAM, is likely to embed the concept in its curriculum, support STEAM research and innovation and adjust its policies and facilities accordingly.

As a response to objective 1, this publication presents a collection of STEAM approaches as well as the themes and intersections that link them.

The handbook shows some of the many different expressions of STEAM from individual, institutional and national perspectives. It aims to provide a shared understanding of what might be achieved by STEAM in Higher Education through identifying foundational competencies and perspectives as well as establishing a baseline of STEAM knowledge.

The project draws a distinction between a 'STEAM approach' and a 'STEAM method'. In general, the former can be considered the wider expression, covering strategies, programmes, fields, and philosophies, whereas the latter more clearly relates to specific techniques. Therefore, this handbook's perspective is that STEAM methods sit within STEAM approaches.

This is the first comprehensive attempt to collect and codify European approaches to STEAM in Higher Education and, as such, the work is exploratory and should not be considered exhaustive. The handbook is intended to stimulate dialogue about the perceived nature of STEAM, its principles and parameters while providing inspiration for those looking to develop and introduce STEAM approaches of their own.

Benefits of STEAM

With its foundations in transdisciplinary working, STEAM provides students with the knowledge and understanding needed for the jobs of the future. STEAM is seen to increase intellectual curiosity and creativity. Its collaborative approach and focus on group working allows individuals to learn socially as well as broadening their perspectives and knowledge. Further, the critical thinking and radical openness elements open routes to innovation.

Depending on the setting of the STEAM activity this innovation can lead to a strengthening of the economy. However, STEAM can also take place outside of the market economy and formal jobs, with softer benefits relating to a wider framing of challenges and the generation of novel solutions. In some contexts, STEAM can make STEM subjects more attractive. STEAM thinking and practices have been used to address complex challenges as well nurturing techniques such as data visualisation to promote understanding of tricky and difficult subjects.

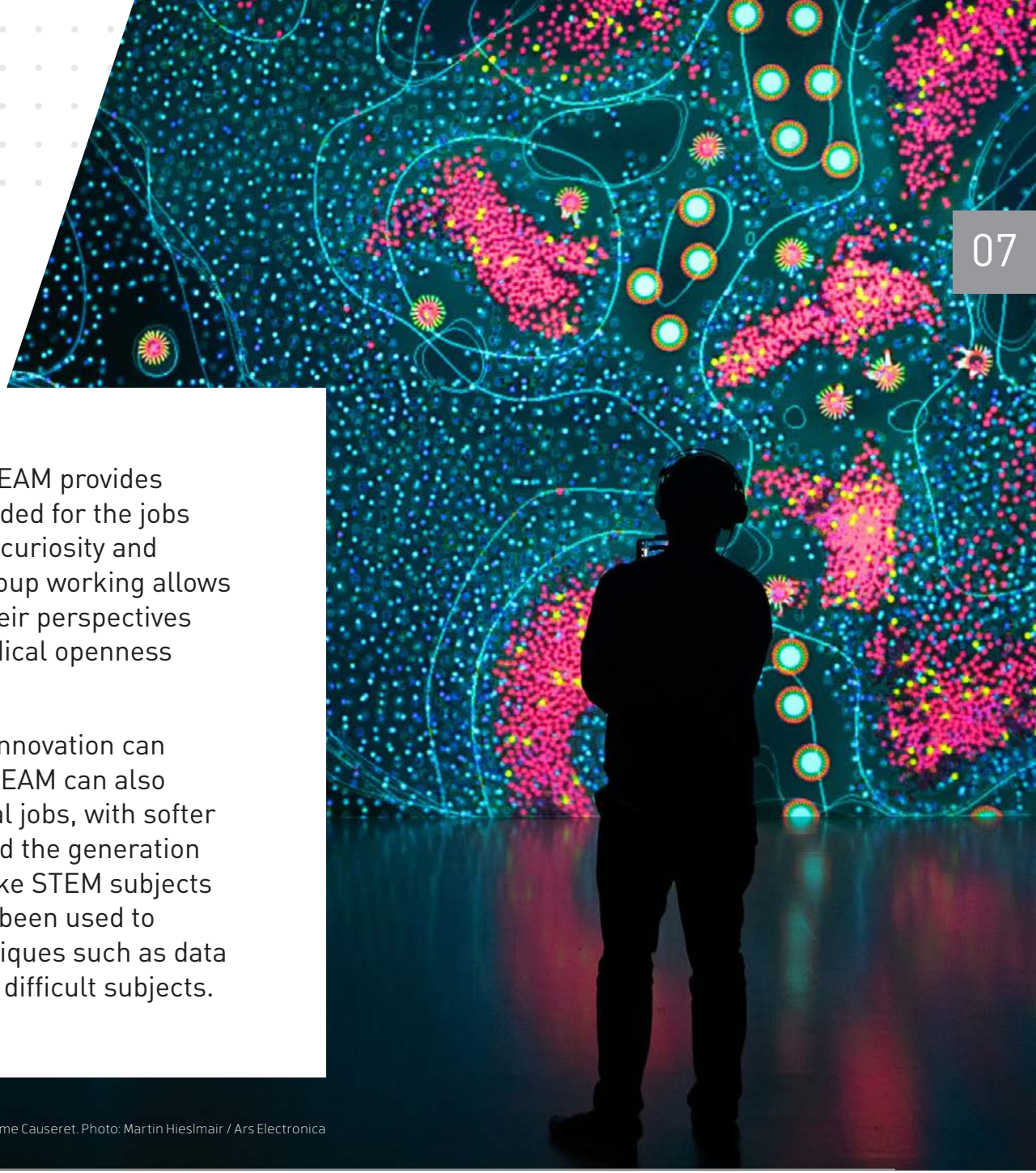


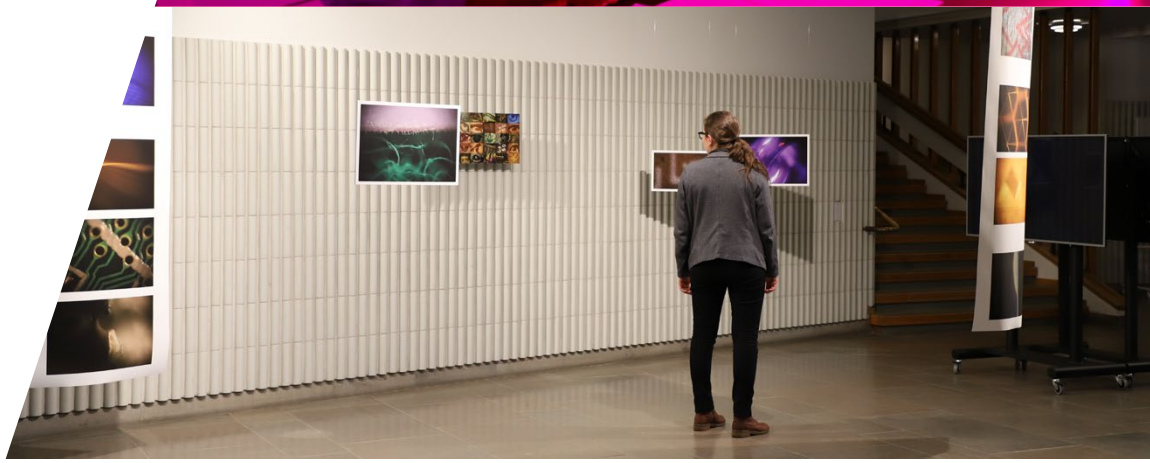
Image: Order from Chaos - Maxime Causeret. Photo: Martin Hieslmair / Ars Electronica

Partners

The STEAM INC partnership consists of six higher education institutions and one cultural organisation, all currently pioneering STEAM approaches. They bring a wealth of experience and foresight in developing and adopting processes that link different disciplines and practices.

- Aalto University, Espoo, Finland
- University of Amsterdam, The Netherlands
- Ars Electronica, Linz, Austria
- Birmingham City University, United Kingdom (lead partner)
- Central Saint Martins, University of the Arts London, United Kingdom
- TU Dresden, Germany
- Science Gallery at Trinity College Dublin, Ireland

More details are included on the project website
https://www.steaminnovation.org



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Methodology

Stage 1: Creating a STEAM approach definition

Before our work could begin in earnest, it was essential to build a common partnership definition of STEAM. This was the focus of the first project meeting, held in Amsterdam in December 2019. Prior to the meeting, each partner supplied individual or team definitions of STEAM, including essential characteristics and context as appropriate. These were presented and discussed in an effort to discern the key elements of a STEAM approach.

Participants then chose the characteristics that they felt were crucial to STEAM. Working in groups, they used a 'Diamond Nine' technique to establish the characteristics from most to least important. Throughout the meeting, there were tensions due to the plurality of STEAM perspectives, the diversity in ways of working and associated preferred collaborative/discursive methods and approaches.

However, the outcomes of the Diamond Nine method provided the key words needed for a definition that would encapsulate the broad, emerging collective understanding of a STEAM approach. This definition is provided below.

Methodology

Stage 2: Collecting and reviewing approaches

Based on the working definition, project partners then identified approaches from within their institutions that contained dimensions of STEAM. These were presented in an online event (due to the Covid pandemic) in March 2020, with each partner supplying two approaches, which resulted in the 14 summaries presented below.

These approaches, the ensuing discussions and reflections form the basis of the practical advice presented towards the end of this handbook. In particular, we identified four intersections that now form the basis of a typology for these approaches. These are: Behaviour, Cultures, Engagement and Spaces. They are further defined below.

Definition of a STEAM approach in Higher Education

The following is the definition that arose during the project meeting described in Stage 1 of the methodology described above.

A Higher Education approach to STEAM potentially involves: a culture (or cultures) that puts the Arts and Sciences on an equal footing

- a paradigm that is process-driven, student-centred, holistic and provides permission to fail alongside being comfortable with uncertain end-results
- a pre-requisite of being collaborative, diverse and delivered through safe spaces
- establishing a mindset of radical openness, flexibility, reflection, experimentation and curiosity
- generating qualities that promote learning, cooperation and multi-modality
- supporting practices that are transdisciplinary and emphasise prototyping and making while considering modes of assessment
- developing competencies of critical thinking, creativity and communication while investigating how these can be applied to generate solutions

Within this definition, particular terms were identified as being most prevalent in STEAM approaches. This created a set of recurring characteristics as that fostered a common understanding for STEAM practitioners.

These are:

- **Collaboration**
- **Critical thinking**
- **Curiosity**
- **Process and process-driven**
- **Radical openness**

Of these, critical thinking was identified most frequently. While this might highlight critical thinking as the core characteristic of STEAM, it should be kept in mind that a successful STEAM approach relies on a combination of all the characteristics indicated above.

By its very definition STEAM is a vast field incorporating Sciences, Technology, Engineering, Arts, and Maths as well as their numerous combinations. In addition, the definition was formed at a very early stage in the collective workings of the partnership and so is reflective of the thinking at that time. It was agreed that it should not be considered absolute but rather recognised as a working definition that could be revisited as knowledge and perspectives evolve. Nevertheless, this definition provides insight into what was collectively determined as relevant within the framework of STEAM.

Approaches

This section presents the STEAM approaches gathered in the second stage of the methodology described above. They are grouped according to the four identified intersections: Behaviour; Cultures; Engagement and Space.

BEHAVIOUR

To work well, STEAM requires behaviours and attitudes that bring value and make a constructive contribution to group working. Participants must be prepared to behave collaboratively, adopting an open mind-set and ready to embrace radical openness. Key behaviours include an acceptance that ideas are not necessarily right or wrong and that trying things out can have as much value as finding a solution. It is also important to have reflective and flexible practitioners who are ready to share experiences and express ideas. Everyone should let others have their turn as well as being content to go with the flow and not stick to a set path.

CULTURES

A healthy STEAM culture accepts, celebrates and thrives on differences as well as seeking diversity and advancing inclusivity. Differences can be discipline, age, experience, ethnicity, job roles and organisational position. This positive culture fosters peer-led support with an open outlook to learning something new. Further, a culture of unlearning, or giving up established knowledge and practices, is a beneficial aspect of a STEAM approach.

ENGAGEMENT

A major characteristic of our STEAM approaches is engagement with external organisations, communities and partners. Indeed, it is often regarded as imperative that STEAM not only involves different disciplines, but people, beyond the organising institution, with different backgrounds, agendas and understandings. This requires an acceptance of ideas in a non-judgemental way, where nothing is deemed incorrect or weak. Important aspects of STEAM engagement include sharing principles and perceptions with communities and establishing a common and understandable language.

SPACE

The final intersection of the STEAM approaches is space. Important features are an area dedicated to STEAM activities that is visible to encourage engagement as well as being safe to allow behaviour and STEAM cultures to be nurtured and flourish. Preferably this is a physical meeting space, but virtual meeting spaces can also be highly suitable for knowledge sharing particularly for national and international collaborations.

Overview of the approaches

BEHAVIOUR

the way that an individual or group acts, particularly in relation to collaboration

CULTURES

the collective values, beliefs and modes of operation which are advocated by STEAM practitioners

ENGAGEMENT

processes which promote open involvement and stimulate wide interest

SPACE

the places from which STEAM activity is delivered

APPROACH	PARTNER	MAIN THEME	SUPPLEMENTARY THEME
Tackling complexity in Information Studies	University of Amsterdam	Behaviour	Engagement
Playful explorations between art and science	Birmingham City University	Behaviour	Cultures
Interdisciplinary dialogues in research and learning	TU Dresden	Behaviour	Cultures
Interdisciplinary collaborations through design challenges	TU Dresden	Behaviour	Engagement
Arts as a route for knowledge building	Aalto University	Cultures	Behaviour
A cross-disciplinary programme on humans, science and technology	University of Amsterdam	Cultures	Behaviour
A catalyst for dynamic exchanges between art and science	Central Saint Martins	Cultures	Space
An undergraduate module addressing societal challenges	Science Gallery at Trinity College Dublin	Cultures	Engagement
Fostering research collaborations across art, technology and society	Ars Electronica	Engagement	Behaviour
Engaging the public with and through steam	Ars Electronica	Engagement	Space
Building relations for transdisciplinary interactions	Central Saint Martins	Engagement	Cultures
A biology lab in an arts school	Aalto University	Space	Engagement
Innovation through STEAMcollaborations	Birmingham City University	Space	Behaviour
An encounter between science and art	Science Gallery at Trinity College Dublin	Space	Cultures

Summaries of the partnership STEAM approaches

The following provides summaries of the 14 approaches presented during the online project event held in March 2020.

Longer descriptions are provided on the project website

www.steaminnovation.org

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Approaches

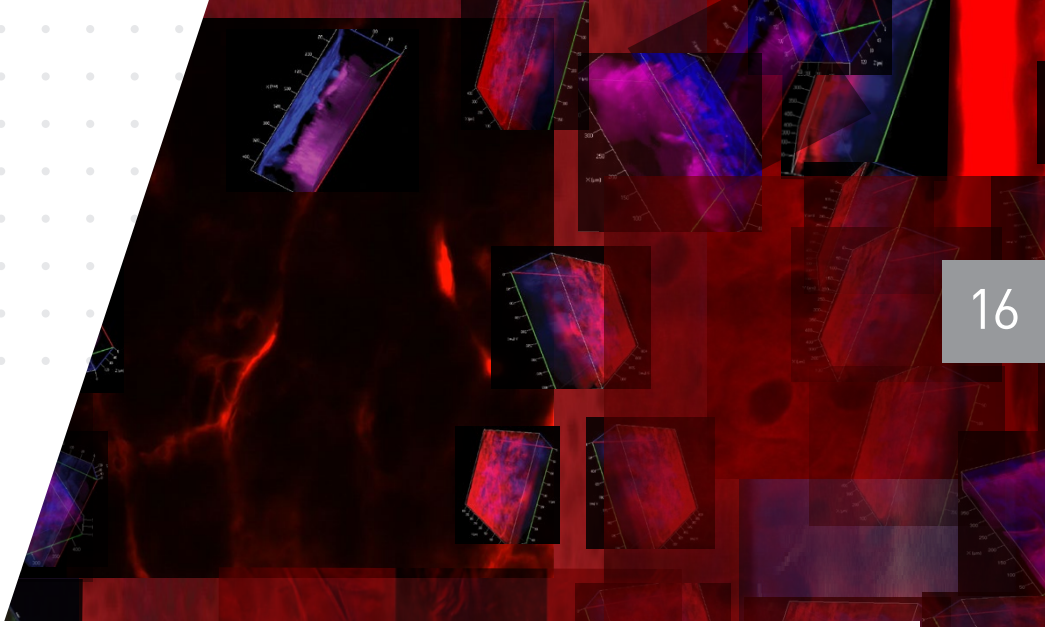
University of Amsterdam

Tackling complexity in Information Studies

Main theme: **BEHAVIOUR** Supplementary theme: **ENGAGEMENT**

This approach covers two degree programmes taught at the University of Amsterdam: the BSc Information Studies (three years) and the MSc Information Studies (one year) which are both located in the Computing Department. Both programmes provide students with room for exploration of the subject through shared activities mainly focused on project work. The aim is to share technological, human and societal insights – including theories, models and system implementations – so that students can comprehend and place themselves within a transdisciplinary productive space. The programmes are aimed at students from a mixture of subject backgrounds but all sharing the desire to solve complex problems, using ICT and digital media.

STEAM is in evidence through the commitment to combining the different domains of technology, society/culture and organisational theory (business-focused and institutional), which creates a reflective system that allows understanding of the complexity of each individually as well as in relation to each other. The courses within the programmes foster personal development and creativity within a scientific environment by providing space for independent work through active learning. The Arts element of STEAM helps to broaden the students' view of technology, specifically that it can provide solutions which help to improve industrial, organisational and social work systems, but that this technology needs to be adjusted to human needs.



Birmingham City University

Playful explorations between art and science

Main theme: **BEHAVIOUR** Supplementary theme: **CULTURES**

The School of Visual Communication, Birmingham City University, is the home of this approach, which was instigated by Jo Berry, PhD researcher and lecturer in illustration. Stemming from an interest in biomedical scientific imagery, the aim is to demystify Art and Science through the use of playful creative methodologies. The result is art works, exhibitions and publications, notably those concerned with digital image explorations, such as light drawings created through the application of laser technology, computer software and material analysis. An evolution of the approach has been an investigation into the creative possibilities of advanced imaging and microscopy, providing new perspectives on the connections between Art and Science.

From a science perspective letting Arts into the working space poses particular challenges which are essential to consider, such as: how to obtain access to research labs; the importance of observing the scientific process in its entirety; similarities and differences between investigative methodologies; and the value of certain decision-making processes which can result in refined forms of play and heightened responsiveness.

The approach investigates Art's value, purpose and interpretational authority, placing it as an equal to Science, and employing play as an essential part of the creative process in generating new methods for, and insights into, using scientific data. Through this, the relationships between science, creativity, culture and aesthetics are explored. The initial research was funded by a Wellcome Trust grant and also supported by the School of Life Sciences at Nottingham University.

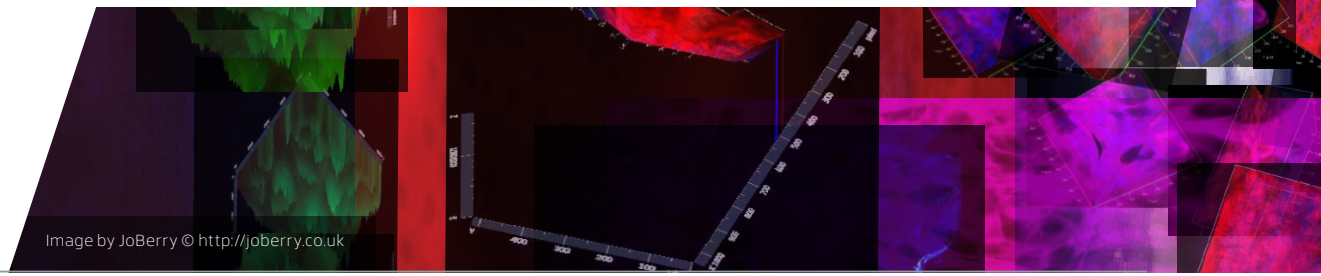


Image by JoBerry © http://joberry.co.uk

TU Dresden

Interdisciplinary dialogues in research and learning

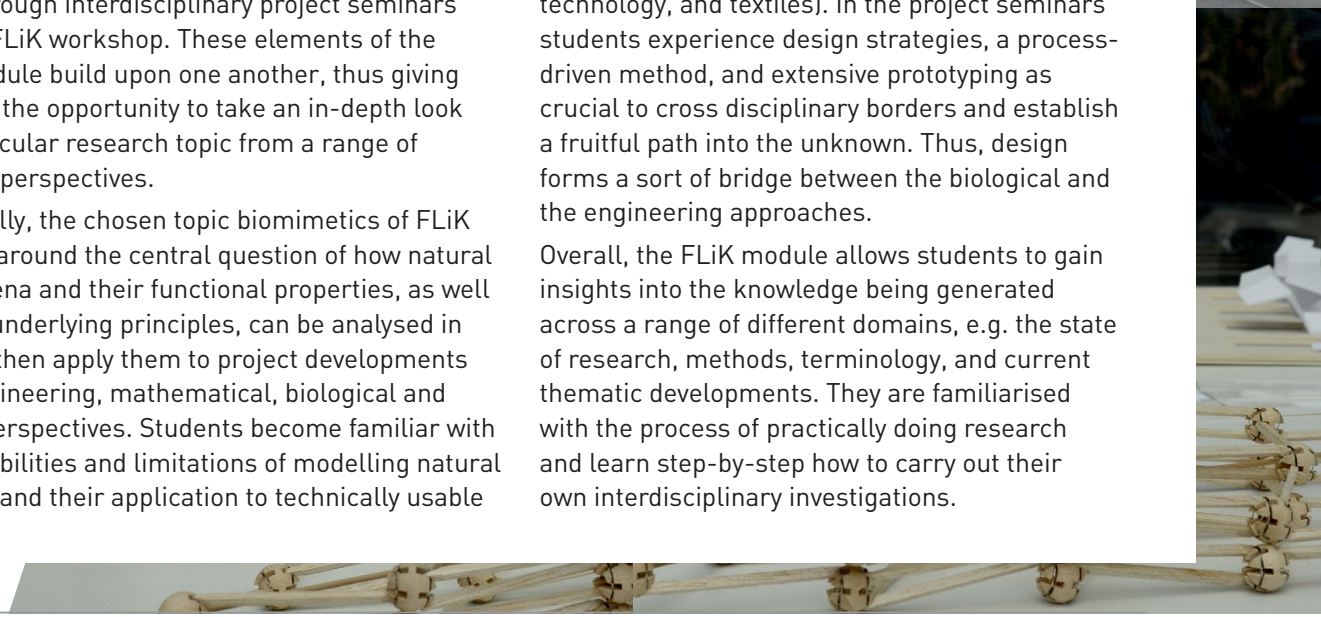
Main theme: **BEHAVIOUR** Supplementary theme: **CULTURES**

FLiK is from the German "Forschen und Lernen im interdisziplinären Kontext": Researching and learning within an interdisciplinary context. The module spans two semesters, starting in the first semester with a series of introductory lectures. Unlike a traditional lecture series, this is taught by several different people – biologists, designers and engineers - each referring to the content of previous and upcoming lectures. Similarities, differences and crossover points between the disciplines are discussed, methodologies are presented, linked and differentiated. This approach, partially with team-teaching elements, is flanked by tutorials and research visits, and enables working out interdisciplinary relationships intensively.
The essential task is to trigger a dialogue between different specialisms, which continues to be nurtured throughout the whole module.

During the second semester, individual topics from the introductory lectures are explored in more detail through interdisciplinary project seminars and the FLiK workshop. These elements of the FLiK module build upon one another, thus giving students the opportunity to take an in-depth look at a particular research topic from a range of different perspectives.

Specifically, the chosen topic biomimetics of FLiK revolves around the central question of how natural phenomena and their functional properties, as well as their underlying principles, can be analysed in order to then apply them to project developments from engineering, mathematical, biological and design perspectives. Students become familiar with the possibilities and limitations of modelling natural patterns and their application to technically usable designs for machines, architecture and materials science (e.g. lightweight engineering, polymer technology, and textiles). In the project seminars students experience design strategies, a process-driven method, and extensive prototyping as crucial to cross disciplinary borders and establish a fruitful path into the unknown. Thus, design forms a sort of bridge between the biological and the engineering approaches.

Overall, the FLiK module allows students to gain insights into the knowledge being generated across a range of different domains, e.g. the state of research, methods, terminology, and current thematic developments. They are familiarised with the process of practically doing research and learn step-by-step how to carry out their own interdisciplinary investigations.



TU Dresden

Interdisciplinary summer course for students

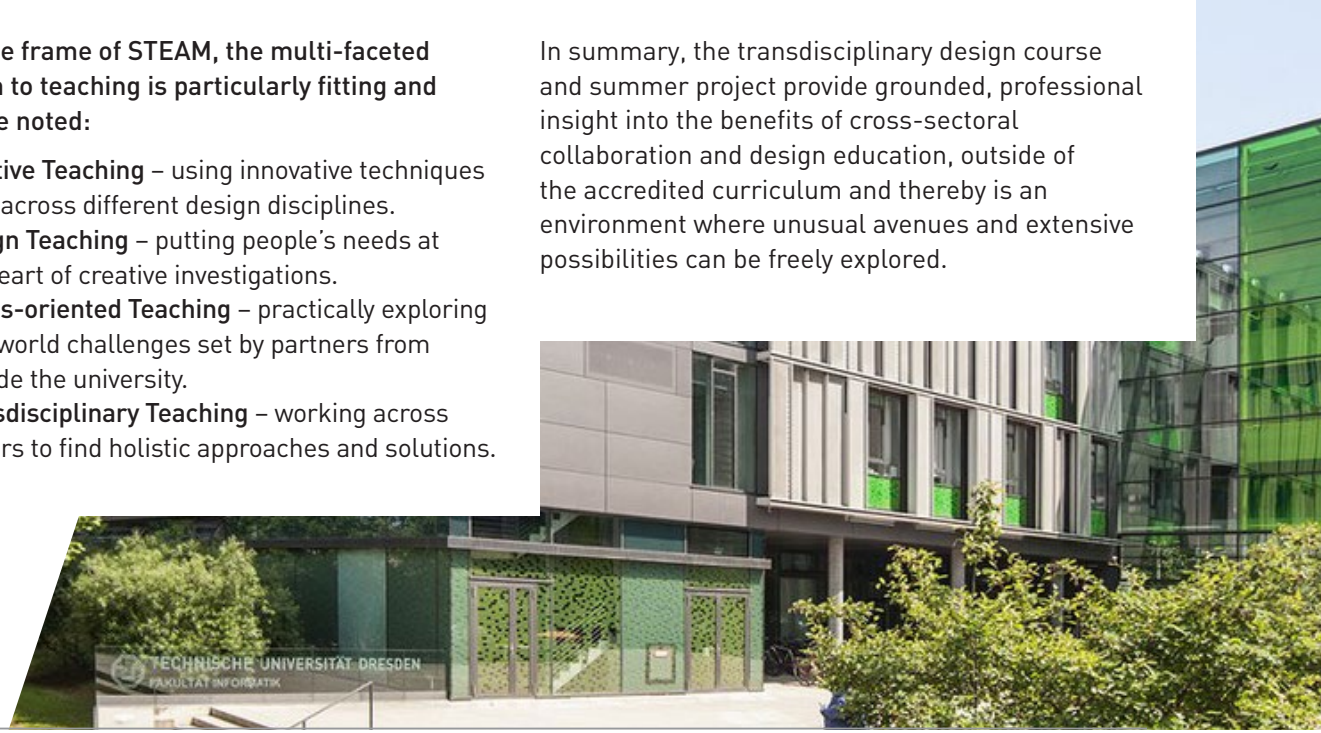
Main theme: **BEHAVIOUR** Supplementary theme: **ENGAGEMENT**

Since 2014, TU Dresden's Industrial Design Engineering has led a transdisciplinary design course and summer project. It brings together students from industrial and media design with those from engineering and technology. Critical to its success are the external partners from industrial and cultural institutions, who provide real-life problems for the students to tackle, as well as giving valuable, professional feedback. The course focuses on human-centred design and human-technology interaction, encompassing all elements of the design process and providing students with hands-on experience of a wide spectrum of tools and methods, including prototyping and presenting at trade shows.

Within the frame of STEAM, the multi-faceted approach to teaching is particularly fitting and should be noted:

- **Creative Teaching** – using innovative techniques from across different design disciplines.
- **Design Teaching** – putting people's needs at the heart of creative investigations.
- **Praxis-oriented Teaching** – practically exploring real-world challenges set by partners from outside the university.
- **Transdisciplinary Teaching** – working across sectors to find holistic approaches and solutions.

In summary, the transdisciplinary design course and summer project provide grounded, professional insight into the benefits of cross-sectoral collaboration and design education, outside of the accredited curriculum and thereby is an environment where unusual avenues and extensive possibilities can be freely explored.



Aalto University

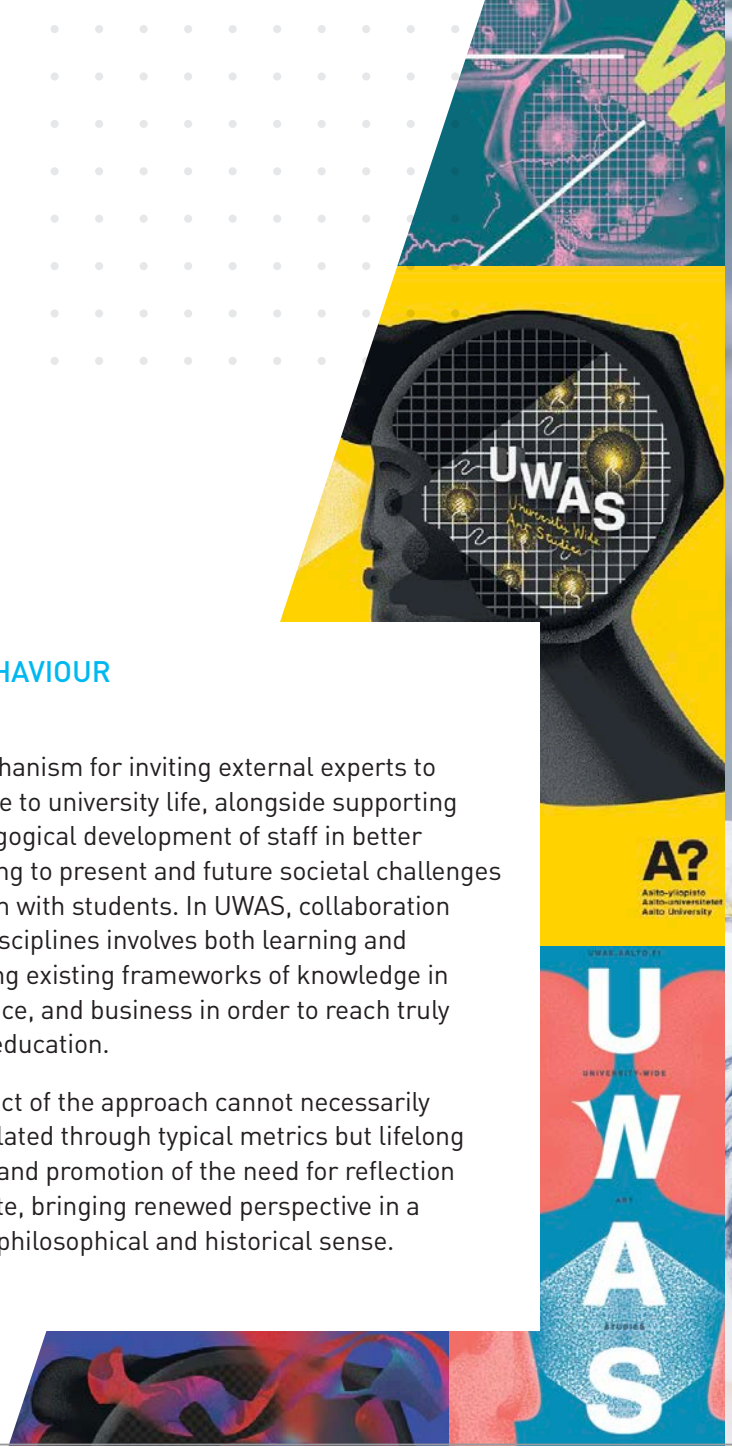
Arts as a route for knowledge building

Main theme: CULTURES Supplementary theme: BEHAVIOUR

The University-Wide Art Studies (UWAS) programme at Aalto University offers all students, irrespective of discipline, the chance to explore and study art and design-based practices and processes. This is a vehicle for the wider ambition of the institution to encourage the formation of transdisciplinary communities of teachers, students and researchers, with a view to tackling global challenges in imaginative and meaningful ways. There is an understanding that art and design should be considered to have a deeper purpose than simply the aesthetic: creativity can help society to be renewed.

The value of the programme is fundamental and, amongst other benefits, can be understood as a mechanism for inviting external experts to contribute to university life, alongside supporting the pedagogical development of staff in better responding to present and future societal challenges in tandem with students. In UWAS, collaboration across disciplines involves both learning and unlearning existing frameworks of knowledge in art, science, and business in order to reach truly dialogic education.

The impact of the approach cannot necessarily be articulated through typical metrics but lifelong learning and promotion of the need for reflection are of note, bringing renewed perspective in a general, philosophical and historical sense.



Approaches

University of Amsterdam

A cross-disciplinary programme on humans, science and technology

Main theme: CULTURES Supplementary theme: BEHAVIOUR

Humans, Science, and Technology (HST) is a programme from the University of Amsterdam with the aim of helping students to address complex and difficult societal issues. It involves three faculties – Humanities, Science and Social Sciences – in combination with four learning trajectories – Change-Making Expertise, Digital Expertise, Humanities and Social Science Expertise, and Research Expertise. It is this hybridity, alongside the capacity to bring about transformations, which is the most reminiscent of STEAM.

HST aims to develop knowledge, mental agility, and bridge-building skills, to create reflective leaders. It adopts an inquiry-based learning methodology, to develop open, creative, and flexible citizens.

With an extensive scope, the programme covers topics such as Design Thinking, literature searches, project and process management, listening and collaborating, as well as personal ethics.

The University of Amsterdam values HST in providing an innovative approach to teaching which seeks to integrate different disciplines, using Design Thinking and associated creative methods of investigation as the main connectors between Science (seen as academic/cognitive) and the Arts (seen as experimental/open).

Central Saint Martins

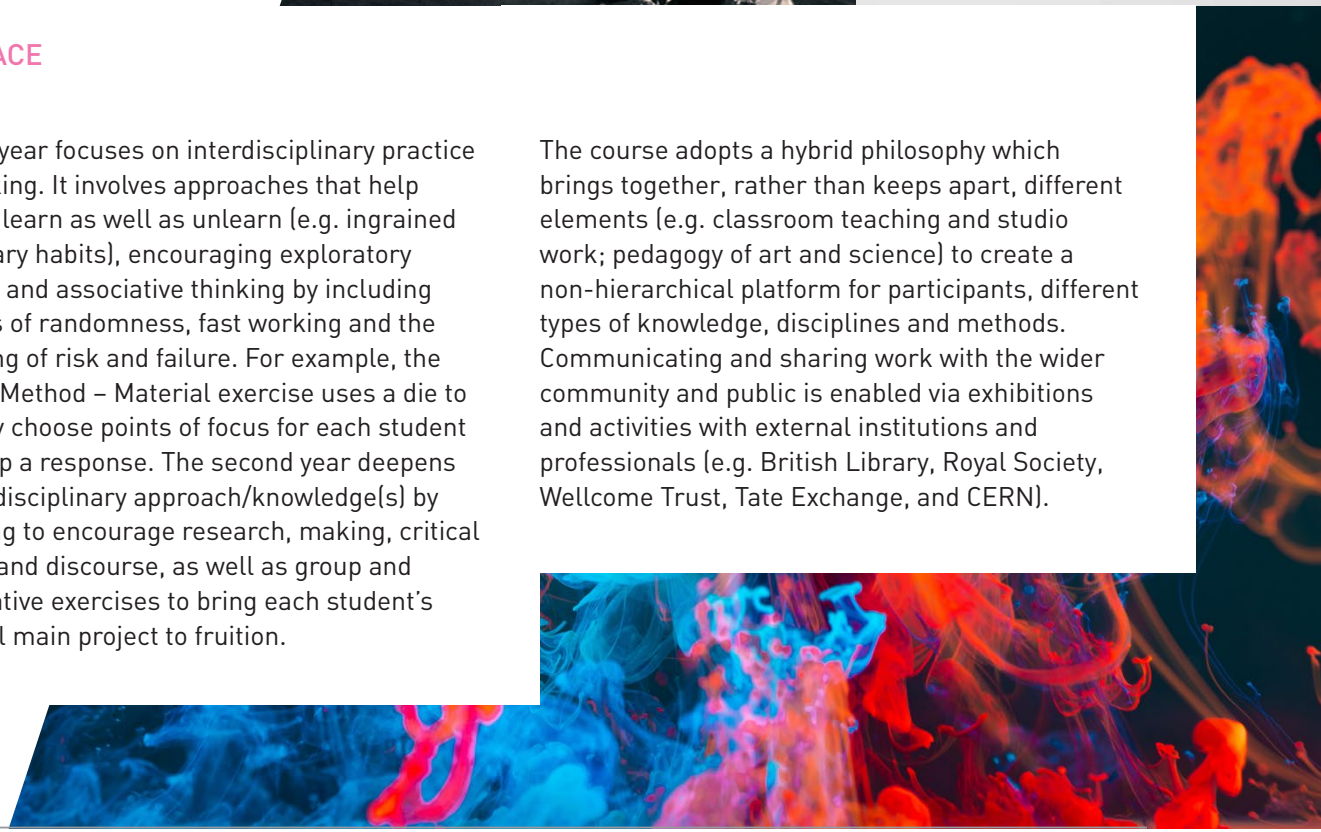
A catalyst for dynamic exchanges between art and science

Main theme: CULTURES Supplementary theme: SPACE

The MA Art and Science (MAAS) is a two-year Master's Degree programme that has been running since 2011, recruiting students from different cultures and disciplinary backgrounds in arts, sciences and humanities. The course has a core teaching team of six, including a Course Leader, Pathway Leader and four Lecturers, complemented by guest scientists, artists and lecturers. It has built a thriving STEAM community, emphasising both teaching and practice, which are facilitated through the involvement of past students. Shared studio spaces are both a resource and a setting for collaboration and cooperation, providing stimuli as well as support for students developing and refining their work.

The first year focuses on interdisciplinary practice and working. It involves approaches that help students learn as well as unlearn (e.g. ingrained disciplinary habits), encouraging exploratory creativity and associative thinking by including elements of randomness, fast working and the embracing of risk and failure. For example, the Matter – Method – Material exercise uses a die to randomly choose points of focus for each student to develop a response. The second year deepens the interdisciplinary approach/knowledge(s) by continuing to encourage research, making, critical thinking and discourse, as well as group and collaborative exercises to bring each student's individual main project to fruition.

The course adopts a hybrid philosophy which brings together, rather than keeps apart, different elements (e.g. classroom teaching and studio work; pedagogy of art and science) to create a non-hierarchical platform for participants, different types of knowledge, disciplines and methods. Communicating and sharing work with the wider community and public is enabled via exhibitions and activities with external institutions and professionals (e.g. British Library, Royal Society, Wellcome Trust, Tate Exchange, and CERN).



Approaches

Science Gallery at Trinity College Dublin

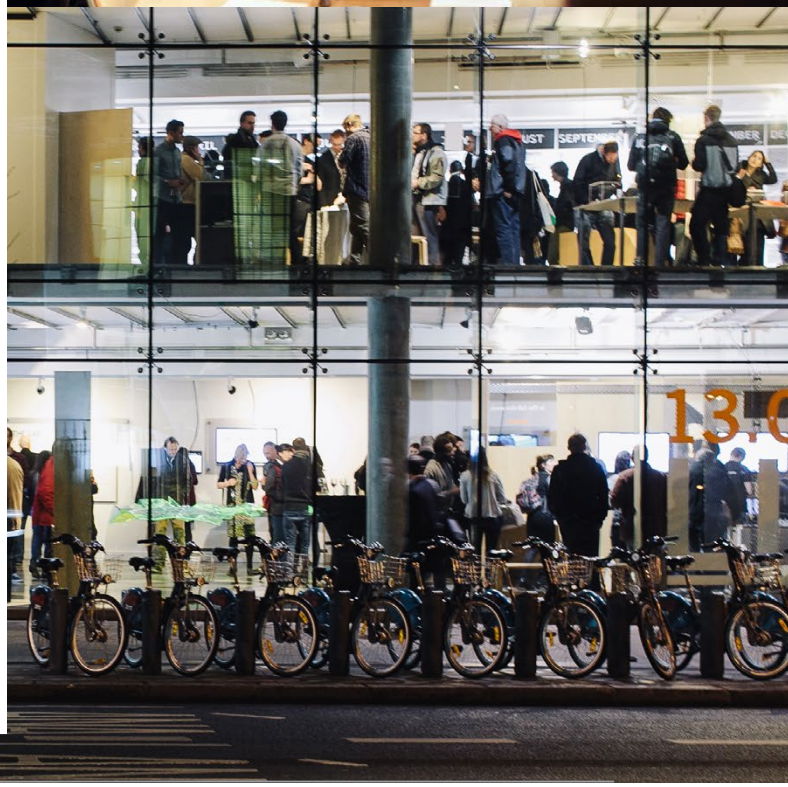
An undergraduate module addressing societal challenges

Main theme: CULTURES Supplementary theme: ENGAGEMENT

The Idea Translation Lab is a transdisciplinary elective module delivered by Science Gallery Dublin for undergraduate students in Trinity College Dublin. The module demonstrates STEAM learning by encouraging collaborative work and creative thinking with the aim of generating solutions to contemporary societal problems. Every year, a different thematic focus linked to the Science Gallery Dublin exhibition is proposed. For instance, in the past issues like bias, systems and health have been explored by the Idea Translation Lab students.

Students engage with a varied curriculum, diverse pedagogies and 'lab' sessions to experiment, design and develop prototypes which are presented and exhibited as part of their learning. Teaching and knowledge acquisition strategies are innovative, taking on board the diversity of students on the programme and their previous insights and understanding.

The outcome enables students to work independently, develop skills such as critical and analytical thinking, while encouraging creativity and imaginative work. The assessment strategy bridges practice and theory by providing opportunities to draw on research expertise, academic content and reflection alongside making, and improving design and communication skills. Students are required to explore the social, scientific and cultural environment in which they are working, supported by an understanding of ethics, public policy and the commercial significance and potential of their ideas.



Ars Electronica

Fostering research collaborations across art, technology and society

Main theme: ENGAGEMENT Supplementary theme: BEHAVIOUR

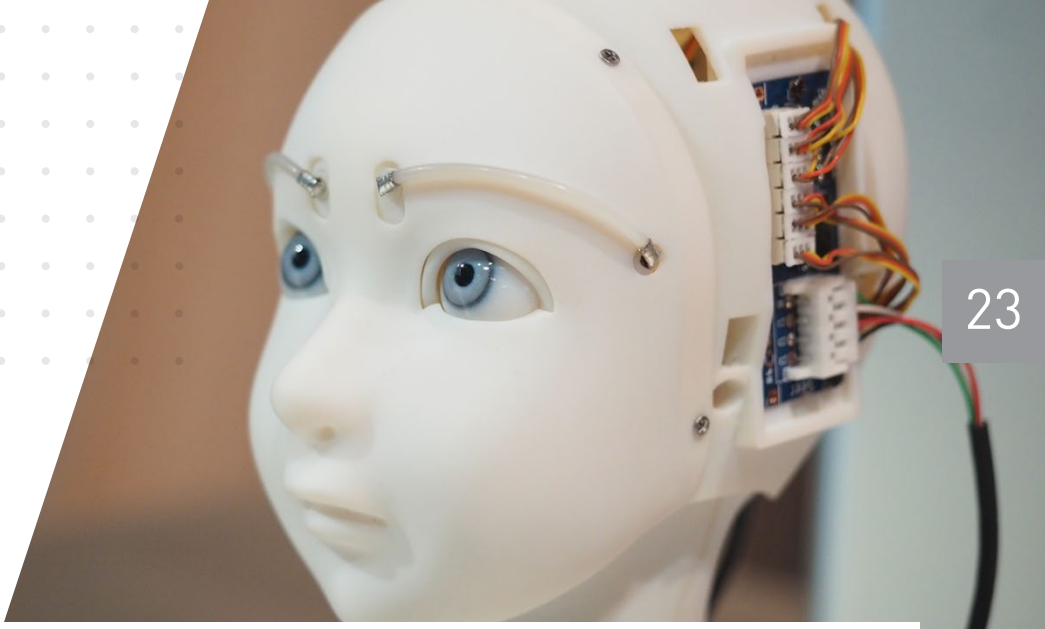


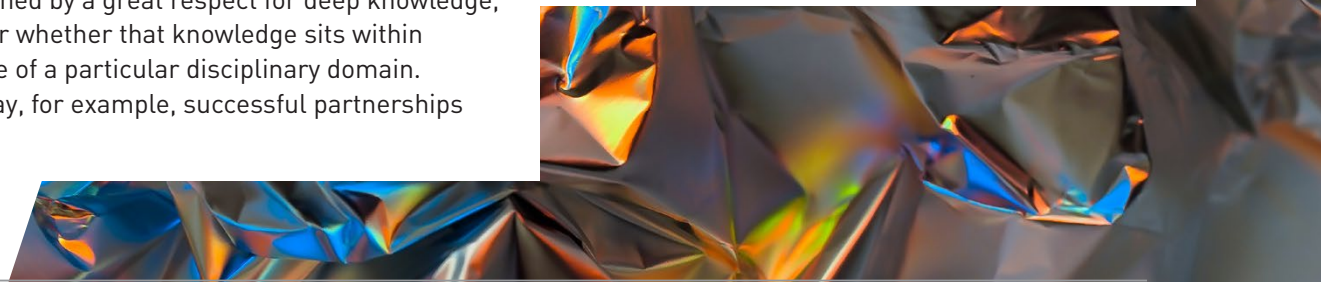
Image: SEER: Simulative Emotional Expression Robot – Takayuki Todo. Photo: Martin Hieslmair / Ars Electronica

While not a Higher Education Institution, Ars Electronica provides perspective on STEAM practice as an organisation that supports a huge range of transdisciplinary researchers across art, technology and society. Of interest is their approach to foster collaborations between artists and engineers, making available physical and intellectual space in which creative and analytical practices can be tested and potentially melded.

Fundamental to this is the STARTS Prize, which provides a platform for promoting collaborations between artists and industry that have led to innovations, and for the creative exploration of technology. One such example is RIAT – The Research Institute for Art and Technology – an independent research cluster based in Vienna, which received recognition in the 2017 edition of STARTS. Investigating the interdependencies inherent in fields such as blockchain, open (source) hardware and experimental publishing. The group received particular note for its research into crypto currencies, which brought to the fore an understanding of how hacker culture can be thought of as having an impact beyond the development of software systems, extending into notions of respect for diverse disciplines and valuing new perspectives.

Such cross-disciplinary collaborations are underpinned by a great respect for deep knowledge, no matter whether that knowledge sits within the frame of a particular disciplinary domain. In this way, for example, successful partnerships go beyond technological mastery and acknowledge the intellectual value of a creative approach and its standing in the wider community.

In essence, when nurturing a collaboration, it is important that time is given for those involved to understand each other on their own terms, before concrete outputs are requested or expected. The value of this approach is in creating the space to experiment, and thus uncovering the unknown, rather than simply finding solutions.



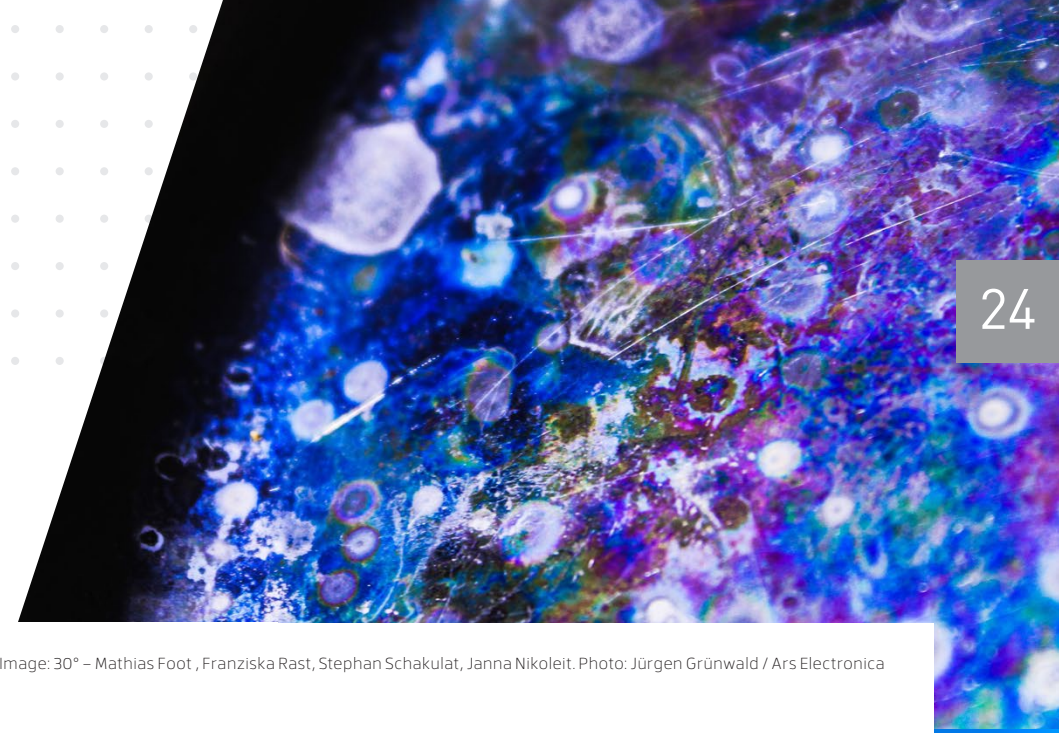


Image: 30° – Mathias Foot , Franziska Rast, Stephan Schakulat, Janna Nikoleit. Photo: Jürgen Grünwald / Ars Electronica

Ars Electronica

Engaging the public with and through STEAM

Main theme: ENGAGEMENT Supplementary theme: SPACE

Ars Electronica organises one of the world's leading media art festivals as well as running a 'Museum of the Future'. Critical to its success is the relationships it builds with its partners and the steps it takes to excite and connect with its audiences. To this end, alongside a pervading need to communicate how technology can shape people's lives, it has established an extensive range of ways to engage stakeholders, including:

- **WE GUIDE YOU** – running tours designed to make Ars Electronica more navigable to the public
- **We Inspire You** – developing an ecosystem of investors, innovators, and policy makers
- **FUTURE Lab** – supporting applied arts and technology research and collaborations with industry

These three strands are all integral to developing connections and each has a defined ambition. Of particular note is WE GUIDE YOU, which provides participants with an opportunity to engage with the thematic focal points of current exhibitions at the Ars Electronica festival. Each tour is unique, as they do not follow a fixed path and new aspects open up during personal exchanges with the Infotrainers (guides). They are often also led by exhibiting artists or thematic experts, including researchers, so providing a spectrum of viewpoints.

The aim of the tours is to educate participants, challenge mind-sets and encourage critical thinking. They are geared towards thinking outside of a solution-focused approach, so emphasising the scope of issues rather than perfect answers.

Participants develop an understanding of Artists and Artistic mindsets, and are encouraged to consider how to create the associations through which STEM and the Arts can become fundamentally connected. This, however, is not a quick process and initial steps can be most effective when focused on encouraging different thinking in individuals rather than relying on the immediate creation of functioning cross-disciplinary groups.

All these activities are underpinned by STEAM, having the intersections of Art, Technology and Society at their core. Ars Electronica also uses the terms STARTS (Science, Technology and the Arts) and Art Thinking to describe its approach.

Central Saint Martins

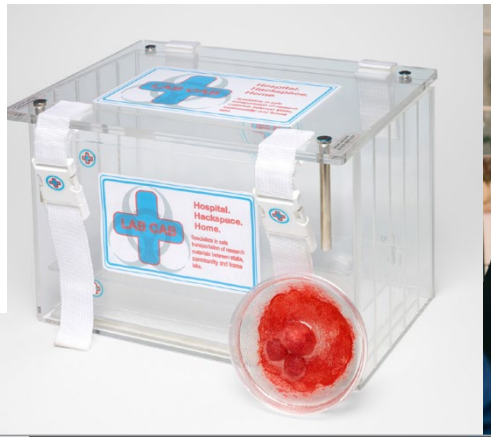
Building relations for transdisciplinary interactions

Main theme: ENGAGEMENT Supplementary theme: CULTURES

Central Saint Martins (CSM) is a constituent college of the University of the Arts London, which, as the name suggests, does not have a science faculty. As part of the process of delivering the MA Art and Science (MAAS) programme at CSM it has therefore been necessary to build relationships with scientific institutions and professionals with whom the students can interact. As the course is situated in central London this facilitates collaborations with a number of institutions including the British Library, the National Gallery, the Science Museum, the Royal Botanic Gardens at Kew, the Wellcome Collection and the Crick Institute.

Projects include the 'Encounters between Arts and Science' exhibition in 2013, which showed art installations in the British Library produced by MAAS students and exploring the interface between art, science and the British Library's collections and building. Also, a collaboration in 2017 with the Royal Society focused on instigating conversations around emerging research cultures, creating artworks that could be used in training sessions for early career scientists to encourage discussion and debate relating to the future of scientific knowledge. Other projects of note include those with Tate Exchange, Government Office for Science, La Joya and CERN, resulting in inter- and trans- disciplinary research, exhibitions and publications.

CSM has also developed many STEAM projects beyond MAAS, such as: Grow Lab – a biology laboratory for art & design teaching and research; initiatives with schools in Camden Borough Council; a Climate Assembly; and MAKE @ Story Garden – a maker space and community garden.



Approaches

Aalto University

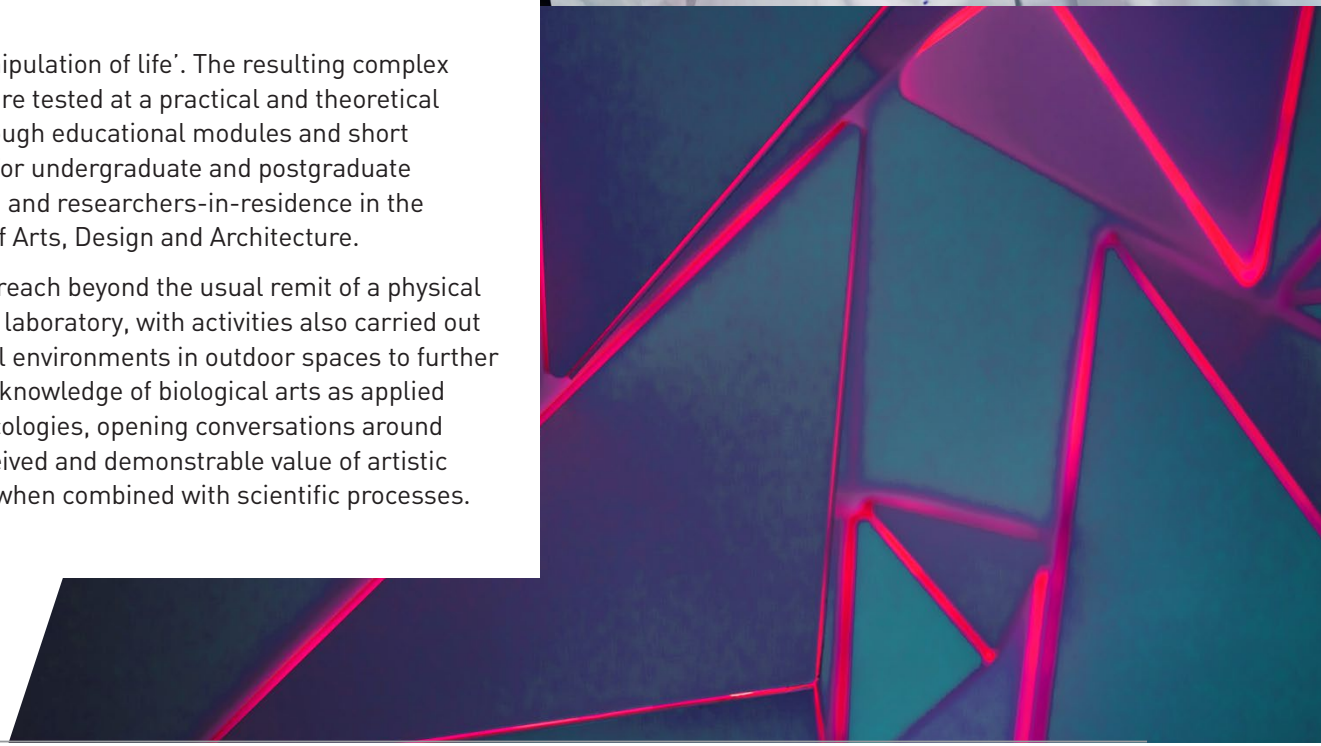
A biology lab in an arts school

Main theme: SPACE Supplementary theme: ENGAGEMENT

Biofilia is a technical facility at Aalto University for studies in the field of BioArt, a fast-emerging area of interest that provides one of the most fitting expressions of STEAM practice, particularly when considering the potential scope of artistic practice. The approach focuses on the creation and adoption of transdisciplinary knowledge to explore intersections between biosciences, engineering and the arts, influencing developments across research and the curriculum.

By placing the lab in an arts school, tools and processes normally associated with engineering and biotechnology can be used as mediums for artistic research, allowing creative investigation of biological processes, organic matter, and organisms, employing such methods as biohacking and 'manipulation of life'. The resulting complex themes are tested at a practical and theoretical level through educational modules and short courses for undergraduate and postgraduate students, and researchers-in-residence in the Faculty of Arts, Design and Architecture.

Projects reach beyond the usual remit of a physical scientific laboratory, with activities also carried out in natural environments in outdoor spaces to further enhance knowledge of biological arts as applied to real ecologies, opening conversations around the perceived and demonstrable value of artistic practice when combined with scientific processes.



Approaches

Birmingham City Univeristy

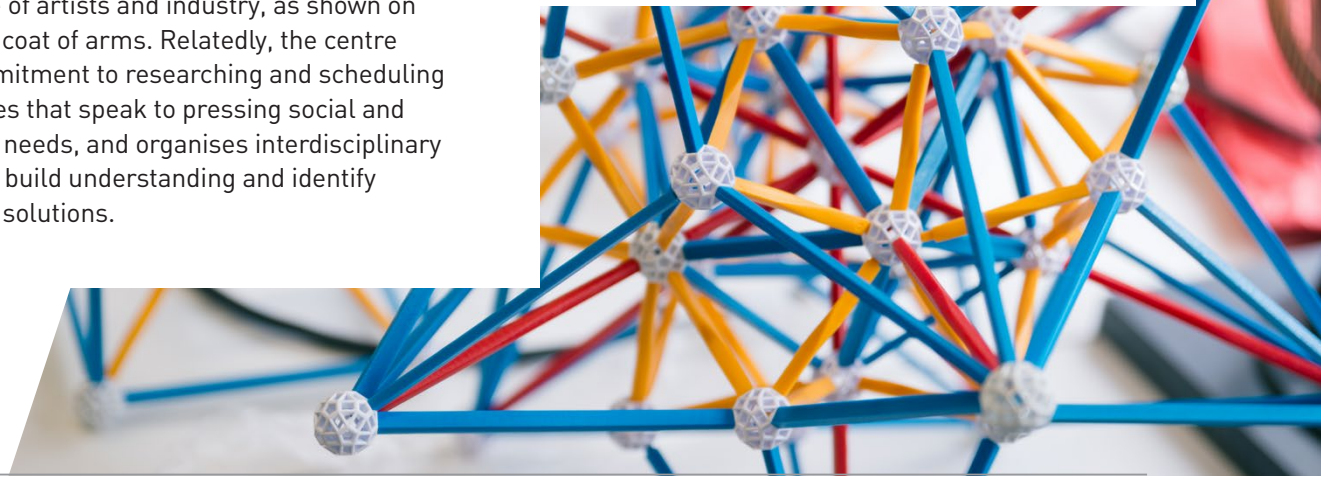
Innovation through STEAM collaborations

Main theme: SPACE Supplementary theme: BEHAVIOUR

STEAMhouse is a centre for innovation, creative thinking, prototyping and business development, which supports artists, engineers, entrepreneurs, companies, and public sector organisations to develop products and services, bringing new ideas to life. It provides access to technical expertise and workshops in wood, metal, print and digital technologies in order to advance people's explorations. STEAMhouse prides itself in building an inclusive community that promotes equality of voice, including input from academics, creative professionals and policy makers. The overall aim is to establish and promote new forms of collaboration that will lead to expanded mindsets and major l ong-term growth across the West Midlands region of the UK.

Fundamental to the approach is the creation of new toolkits that help people adopt STEAM perspectives – these focus on five key principles: collaboration, conversation, exploration, newness, and openness. This ethos resonates with Birmingham's civic history, which has a tradition of combining the expertise of artists and industry, as shown on the city's coat of arms. Relatedly, the centre has commitment to researching and scheduling challenges that speak to pressing social and business needs, and organises interdisciplinary events to build understanding and identify potential solutions.

STEAMhouse is a partnership between Birmingham City University and Eastside Projects and is funded by the European Regional Development Fund, Arts Council England, and the Greater Birmingham and Solihull Local Enterprise Partnership.



Approaches

Science Gallery at Trinity College Dublin

An encounter between science and art

Main theme: SPACE Supplementary theme: CULTURES

With a mission to ignite creativity and discovery where science and art collide, Science Gallery Dublin's approach is primarily focused on youth engagement (15-25 year olds) through unique, transdisciplinary exhibitions, events and educational programmes. It offers a social space to develop and explore ideas, using performance and interactive experiences as a key for audience engagement. Pioneered by Trinity College Dublin, Science Gallery Dublin is the founding member of the wider Science Gallery Network, with each facility being part of a leading university.

Science Gallery Dublin co-creates work with scientists, artists and youth advisors which responds to global challenges through a combination of art, science and technology. A key consideration in maintaining balanced engagement from diverse contributors and audiences is to use a cross-sector 'common' language to open up conversations. The approach seeks to achieve a balance where Arts and STEM thinking are treated with equality; artists and scientists developing work at the junctions of the two disciplines. This supports the notion that transdisciplinary approaches to education and innovation are fundamental to future-proofing universities. In each network location, the situated Science Gallery acts as a porous membrane between the university and the city. It supports co-existence and respect across both cultural and academic spheres, as well as developing connections with local community stakeholders.

Implementing a STEAM approach

Initial considerations

In instigating a STEAM approach in a Higher Education setting there may well be a conflict between the open, non-hierarchical principles of STEAM and the pre-existing structures of an Institution. STEAM's emphasis on process, group work and transdisciplinarity is likely to challenge Higher Education Institutions with their obligation to measure outcomes and assess individual student capabilities, potentially in narrow subject silos.

However, our approaches have shown that, in presenting the right rationale, Higher Education will embrace STEAM thinking and gain from its benefits outlined earlier. However, be aware of the potential barriers in your Institution that may dilute or even prevent your STEAM approach.

One fundamental action is to gain support from senior management in your institution. You will need trust and confidence if resources are to be allocated. Do people in your institution really know what STEAM is and how they might benefit? Arrange specific training or discussion groups to generate momentum. Help others to act as advocates, talking knowledgably about what STEAM means to them and its positive outcomes.

Also consider:

- How the STEAM approach supports institutional strategies and key performance indicators.
- The likely return on investment. Will the approach generate new funded research opportunities and/or attract additional students?
- The gap in the market that your STEAM approach will address - is this academic, external, a combination, or other? Ideally, this work should be supported or led by trusted academics from within your own institution.
- The authorisation and governance processes and systems, including the particular individuals, committees and boards who will need to provide consent and the timescales for decisions (internal and external).
- The curriculum and learning outcomes required by your institution (if applicable). Alternatively, the outputs and outcomes required by external partners or funding streams, as appropriate.
- Any other processes that people previously undertook to deliver succesful change programmes. Are there any prevailing barriers that must be overcome before a new approach, STEAM or otherwise, will be adopted?
- What existing academic research, projects or courses in your institution speak to STEAM principles?
- How might the approach translate across your organisation. For example, will toolkits for course design be produced that might be used by other departments? What additional value might your approach bring?
- What are your objectives – what outcomes are you hoping to achieve?
- Are you creating a full formal course, a module or a project?
- Who do you want to participate in the STEAM activity? Students, academics, members of the public, external partners or organisations or a combination of some or all of these?

Focus on projects

A STEAM approach is likely to involve a group with different backgrounds working together as a project team to explore a specific task or challenge. Key are the notions of a voyage of discovery and an investigation into the possibilities of collaborating, fusing ideas and combining knowledge.

Group formation

By its very nature, STEAM requires transdisciplinary groups to function. As discussed in the Introduction (and highlighted in the Approaches section) not every constituent discipline or field encompassed by the term STEAM needs to be present in every project, but our approaches confirm that there needs to be an arts and a technical or sciences element.

Projects often involve external partners, creating an opportunity to embed different perspectives. Try to involve people from beyond the usual disciplines or close contacts; for example, include the wider public and/or connect with decision-makers and potential users if appropriate.

Be careful not to treat STEAM as a tick-box exercise or put all the success and burden onto the Arts element. Avoid situations where the inclusion of the Arts is superficial, naïve or tokenistic (such as, ignoring the critical inquiry elements of the Arts and only seeing them as producing aesthetically pleasing outputs). Where Arts is the catalyst for a project be careful not to ignore or supress the creative elements within the other contributing disciplines.

Language

The group will need to adopt a common language to function. Try to identify words that are not exclusive to particular professions and help to build bridges between disciplines through clarity of thought and expression. Take time to explore and understand differences and synergies in the use of terms, theories, approaches and concepts favoured by participants. However, do not dwell unnecessarily on these. Instead, be open to simpler, accessible language and ways of communicating.

Topic choice

If a topic is to be chosen, it helps to avoid relying solely on descriptions that use conventional disciplinary terms. Try to weave in consideration of broader issues and contemporary themes that affect society. In addition, what is considered conventional might change from person to person and group to group, so there is value in running projects more than once, with different participants to map out the boundaries that a subject area might reveal and the methods that work for particular people in specific circumstances.

Scale

Linked to topic choice is the notion of project scale. It is not necessary to solve the biggest challenges straight away. It is seductive to imagine that STEAM, with its infinite possibilities, might immediately uncover a transformative approach. The reality is that it is fine to start small and build up over time. Focus on supporting the behaviours that allow people to feel rewarded for making meaningful suggestions, even if they only result in incremental change.

Reflections

Sharing the results and outcomes of STEAM projects, investigations and discussions is useful for aiding reflection on specific strengths, weaknesses, opportunities and barriers. Do not limit your deliberations just to the end of the project, but try to build in points for considering progress and learning throughout the project life cycle. In short, a STEAM practitioner can learn how to better deliver STEAM projects from the projects themselves.

Behaviour: the way that an individual or group acts, particularly in relation to collaboration

Keywords: collaboration; experimentation; group working

- **COLLABORATION:** make sure that people understand that they need to be happy working with others and contributing to the group.
- **GROUP WORKING:** encourage a lack of hierarchy and promote an equality of subject area. Do not force everyone to behave in the same way. Foster a setting where different behaviours can interact. Be prepared to facilitate, support and feedback.
- **EXPERIMENTATION:** nurture conditions that persuade participants to try new ways of doing things, accept that things are not necessarily right or wrong and cope with failure or a lack of a clear ending. Ask participants to imagine possibilities beyond those that normally sit within their frame of reference. Celebrate when individuals or groups try something new.

Examples:

Tackling complexity in Information Studies: University of Amsterdam

This programme employs methods from narration and visual arts, discussions about ethics as well as design thinking so that students understand that information and data are not only applicable in business-oriented contexts but can also be treated playfully.

Playful explorations between art and science: Birmingham City University

Through investigating playful and artistic interpretations of scientific data collaborative behaviours and the potential of cross-disciplinary perspectives are highlighted.

Interdisciplinary dialogues in research and learning: TU Dresden

By promoting transdisciplinary viewpoints, this example encourages wider definitions of disciplines than might ordinarily be the case, laying the foundations for STEAM practitioners to emerge

Interdisciplinary collaborations through design challenges: TU Dresden

Collaborative behaviours run throughout this approach, from developing external partnerships to promoting cross-disciplinary investigation. Real-world challenges provide students with insights into professional practice and STEAM is embedded though valuing different kinds of creativity.

Cultures: the collective values, beliefs and modes of operation, which are advocated by STEAM practitioners

Keywords: values; multi-modality; positivity; unlearning

- **VALUES:** exhibit your STEAM values clearly so that your community understands how you intend to operate. Be open to discussion. Consider how your STEAM values map on to those of your institution.
- **MULTIMODALITY:** encourage different formats for presenting ideas, information and outcomes, including writing, graphics, symbols, film as well as spoken language and narratives.
- **POSITIVITY:** create a positive culture in STEAM projects by fostering peer-led support and an open attitude to new ideas and suggestions.
- **UNLEARNING:** focus on forgetting current knowledge and practices and acquiring new perspectives, breaking down preconceptions and seeking the unknown. Investigate what could underpin or undermine an idea and develop new baselines. If you know that participants have tackled a particular challenge in a certain way before, ask them to think of a different one.

Examples:

Arts as a route for knowledge building: Aalto University

Notable in this approach is the non-hierarchical culture which supports the programme. No previous knowledge is required nurturing an environment in which new connections can be established, creating meeting points for students and staff.

A cross-disciplinary programme on humans, science and technology: University of Amsterdam

This far-sighted programme seeks to combine understanding of science and technology with the concerns of humans through connecting STEM with the Humanities. It is an emphasis on change-making that most resonates with STEAM, emphasising what can be achieved through new combinations and permutations.

A catalyst for dynamic exchanges between art and science: Central Saint Martins

Students go through a process of unlearning before producing an output. They are encouraged to break down preconceptions to acquire new perspectives and knowledge.

An undergraduate module addressing societal challenges: Science Gallery at Trinity College Dublin

Through exhibitions, students gain access to a broader audience for sharing ideas and gaining constructive feedback. Additionally, students are invited to grapple with important societal issues in a setting that encourages theoretical examination and critical reflection, in tandem with practical skills including designing and prototyping.

Engagement: processes which promote open involvement and stimulate wide interest

Keywords: acceptance; communities; partners; technology

- **ACCEPTANCE:** ensure that people understand that they will not be penalised for moving into areas in which they are less competent or confident, so that they partake fully in a STEAM process.
- **COMMUNITIES:** to develop trust and understanding, involve your partners and community before the STEAM process starts, so that they feel empowered and actively engaged from the start.
- **PARTNERS:** inform partners of STEAM's history and principles, possibly through an initial workshop or presentation before any significant work is started. Establish a common understanding using techniques such as feedforward and feedback. Provide people with a chance to explore and restate their findings.
- **TECHNOLOGY:** use technology (as with language in the project section above) in an inclusive way. If necessary provide training so that any shared platforms allow equal access and understanding.

Examples:

Fostering research collaborations across art, technology and society: Ars Electronica

This approach demonstrates the importance of establishing a mutual understanding and equal footing when building partnerships. Arts and technology participants experiment and explore the unknown, allowing innovative ideas to emerge from the collaboration.

Engaging the public with and through steam: Ars Electronica

By breaking down the barriers often encountered in curated festivals and exhibitions, a dialogue is opened up between stakeholders, allowing an exploration of roles and impacts while encouraging people to feel more connected to the work on display.

Building relations for transdisciplinary interactions: Central Saint Martins

Through this approach a large range of STEAM projects and partners are engaged and supported. These include work with schools, makers, bio-artists, climatologists and a community garden. Overall, the approach shows the impact that a Higher Education Institution can have when committing to transdisciplinary collaboration.

Space: the places where STEAM activity is delivered

Keywords: cross-over; visibility; connectivity; customisability

- **CROSS-OVER:** consider differentiating where discussions take place from where things are made. However, if possible, include an area where crossover between production and thinking can happen. Allow resources to be shared, with equal permission for use across disciplines.
- **VISIBILITY:** display equipment and activity openly so that visitors and other interested partners can see what the space is used for and how they can engage with it.
- **CONNECTIVITY:** if possible, connect to the public realm (need elaborating?) through a civic space to promote wider engagement and provide material for stimulation.
- **CUSTOMISABILITY:** add features that help the community to tailor their environment and promote ownership. For example, movable blackboards, sliding walls, customisable furniture and glazed partitions. Enable a common ground that is free from hierarchies.

Examples:

A biology lab in an arts school: Aalto University

Biofilia treats the Biological Sciences and the Arts as equals, allowing layered exploration of the natural world. Artists can help present complex and latent technological ideas through creative forms, making them accessible and open to further debate in society.

Innovation through science, technology, engineering, arts and mathematics collaborations: Birmingham City University

STEAMhouse nurtures the creation of new products and services for businesses through STEAM based activities. The open-access space includes prototyping equipment as well as fostering behaviours that stimulate collaboration across artists, engineers and designers.

An encounter between science and art: Science Gallery at Trinity College Dublin

This approach offers spaces where young people can engage with science in a creative and divergent way. At the junction of STEM and the Arts, often provocative installations surprise and engage visitors, helping them understand the breadth and variety of applications connected to scientific concepts and discoveries.

Tensions and ambiguities

As our approaches show, STEAM can uncover multiple perspectives as well as identifying or providing bridges, nodes and points of intersection through an investigative process. However, this exploratory mind-set can engender a number of tensions or ambiguities discussed in the following. It is helpful to be aware of these and associated potential pitfalls when building an approach.

Possibly the biggest tension, for curricular-based STEAM activities is the need for educators to measure the extent to which students have met intended learning outcomes. Further, research and other external funding streams often demand quantifiable outcomes and clear indications of impact. Clearly STEAM characteristics such as critical thinking, non-hierarchical working and a collaborative approach do not immediately lend themselves to conventional forms of measurement and assessment. This dilemma will be addressed in the third part of the STEAM.INC project. In the meantime, a STEAM approach needs careful consideration of outcomes and how they will be evaluated. Much can probably be learnt here from existing Arts-based assessment experiences and practice.

Not unrelated, is the nature of group working. As it is based on transdisciplinary projects, STEAM relies on group work to be successful. Further, projects may involve local communities, collaborating with businesses or other forms of external engagement. Here, it may be difficult to distribute marks fairly, and recognise the different inputs that participants have made.

An ambiguity is the lack of clarity regarding how much of each of the separate elements of STEAM should be present for an activity to be considered to be STEAM. Debates include if A is being added to STEM, STEM is being added to A, or STEM embraces or, alternatively, smothers A to result in STEAM.

STEAM thinking and practice have changed over time and will continue to do so. This may make it hard to pin down STEAM but also keeps it exciting and relevant. For example, hands-on MakerSpaces signify early STEAM action and remain an important part but there has also been a trend towards more discursive, reflective and philosophical labs. Furthermore, a widening of techniques, including play, can be observed offering effective and safe ways to experiment. This is shown in the embracing of failure as an inherent part of experimental processes and a positive driver for innovation.

Although STEAM activities are largely still extra-curricular, we have started to see a rise in STEAM modules and courses, with research and attention to STEAM steadily increasing across Higher Education. Importantly, STEAM approaches do not only stimulate transdisciplinary working, critical thinking, creativity and innovation, they also lend themselves to being inherently inclusive and reflective.

STEAM INC

STEAM Approaches Handbook

Erasmus+

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