HYBRID
LAB NETWORK

HYBRID LABS ON TRANSDISCIPLINARITY: KNOWLEDGE THROUGH EXPERIENCE

Co-funded by the
Erasmus+ Programme
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BEST PRACTICES BOOK (IO4) AND
CONFERENCE PROCEEDINGS

HYBRID LABS ON TRANSDISCIPLINARITY: KNOWLEDGE THROUGH EXPERIENCE

Best practices book (IO4) and Conference Proceedings

1st Hybrid Lab Network Conference
STEAM AND THE FUTURE OF EDUCATION
Interdisciplinary Innovation and the Integration of the 4 Cultures Domain
19-20 September 2022 | Porto, Portugal

Editors: Matej Mertik, Institutum Studiorum Humanitatis, AMEU-ISH; Maria Manuela Lopes, i3S and IBMC; Laura Beloff, Aalto University; Lucas Evers, Waag Society

Contributors: Maria Rui Vilar Correia, i3S and IBMC; Júlio Borlido Santos, i3S and IBMC; Anabela Nunes, i3S and IBMC; José Bessa, i3S and IBMC; Anna Olsson, i3S and IBMC; Marta Mendes, i3S and IBMC; Polona Tratnik, Institutum Studiorum Humanitatis, AMEU-ISH; Aurora Del Rio, Aalto University; Kas Houthuijs, Waag Society

Reviewer and proofreading: Daisy Hildyard (Hybrid Labs on Transdiciplinarity: Knowledge through Experience)

Technical arrangements and design: Tjaša Pogorevc

Edition: online

Place: Maribor

Publisher: AMEU – ECM, Alma Mater Press

For the publisher: Ludvik Toplak

Year: 2022

Available at: https://press.almamater.si/index.php/amp/catalog/book/48

Grant Agreement No 2019-1-PT01-KA203-061449
ERASMUS+ PROGRAMME – KA2 – STRATEGIC PARTNERSHIP
"The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein."

Co-funded by the Erasmus+ Programme of the European Union

CIP - Kataložni zapis o publikaciji

Univerzitetna knjižnica Maribor

378:004.5(082)(0.034.2)

HYBRID Labs on Transdisciplinarity: Knowledge Through Experience [Elektronski vir] : best practices book (IO4) and Conference Proceedings / [editors Matej Mertik ... [et al.] ; contributors Maria Rui Vilar Correia ... et al.]. - E-publikacija. - Maribor : AMEU - ECM, Alma Mater Press, 2022

Način dostopa (URL): http://press.almamater.si/index.php/amp/catalog/book/48
ISBN 978-961-7183-07-8
COBISS.SI-ID 131730691

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1.

INTRODUCTION

1.1 DEFINITION

HYBRID (Hybrid Lab Network - https://hybrid.i3s.up.pt/) was an ERASMUS+ project that promoted innovation and creative practices for Higher Education (HE) institutions bridging areas of art, science, technology/engineering and the humanities. HYBRID fostered collaboration, knowledge sharing, and training. It aimed to cultivate reflection and to initiate real action to identify the best pathways for higher education in the future, across the **4 Cultures - Arts, Sciences, Engineering/Technology and Humanities**, and **3 Sectors - Academia, Research and Society.** HYBRID developed an approach for equipping the workers of the future with an interdisciplinary understanding that embraces the **creative thinking, innovative skills and collaboration** that will be necessary to consolidate new experimental teaching/learning methodologies.

HYBRID set out with an iterative and progressive structure and evolved accordingly, culminating with the launch of this booklet on good practices for **collaborative innovation for higher education.** It followed a design-thinking-based strategy and adopted exploratory methodologies with the aim of devising formative proposals for STEAM in higher education. The challenge was determined at the outset, when the project was submitted to the ERASMUS+ programme: **to create integrative learning/teaching spaces for higher education participants of multidisciplinary backgrounds.**

The HYBRID implementation process strived to be interactive and humanized, abiding by the trial-and-error approach that was a core tenet of the project. However, it also entailed a recurrent practice of systematically identifying and redefining our students', partners' and participants' needs and expectations.

Professors, researchers, students and invited experts worked closely to design the proposed training actions. This was crucial to the process. It enabled the roundup of diverse viewpoints from people with distinct backgrounds and experiences, sharing a common goal: the effective creation of the above-mentioned integrative educational spaces.

1.2 PROJECT OVERVIEW

HYBRID project ran from September 2019 to November 2022 and involved four European partners, each of whom have developed HYBRID endeavours to varying degrees. HYBRID project defined three key objectives:

1. To **promote excellence in teaching** and skills development in Higher Education (HE). This involves linking education with research and innovation, and fostering open, innovative and entrepreneurial processes.
2. To **promote** teaching and learning **partnerships** with international public and private sector partners.
3. To enhance the experience of **international cooperation** by strengthening capacities in interdisciplinary learning/teaching.

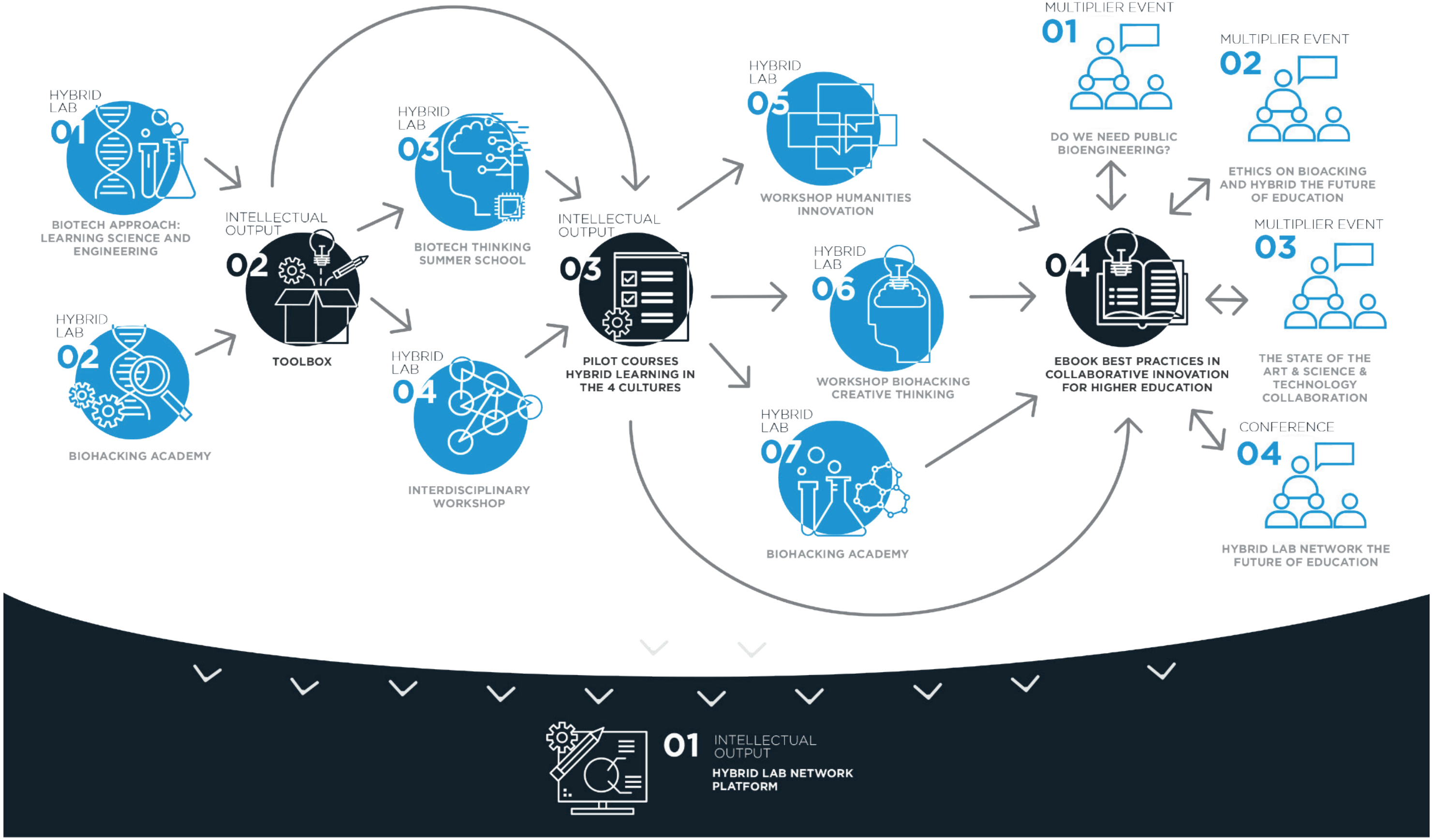
HYBRID and its outputs emerge from **an analytical, experimental and creative process that involves different people designing, testing and prototyping teaching/learning tools and experiences (LTTAs – hybrid labs).** Participant feedback was worked back into the proposals, as they were redesigned or refined in phases. The project initially involved two distinct phases, Problem Definition/ Understanding and Ideation (HYBRID LAB 01 and 02). The first phase consisted of generating and exploring ideas for viable training actions, and of prototyping proposals for tools that would work with the training modules (IO2 TOOLBOX). Subsequent Testing and Implementation phases involved running the suggested training actions, using the framework that was set out in the formative proposals (HYBRID LAB 03 and 04). This gave rise to four new and differentiated formative proposals. The new proposals, when woven back into HYBRID's guiding principles, were more complex than the initial proposals (IO3 - Pilot Courses modules). The four formative proposals – or courses – were once again put through Ideation (HYBRID LAB 5, 6 and 7): the courses were tested, either in total or in part. As in previous phases, **engaging end users as the process unfolded was one of the most important features of this phase. Both students and professors contributed to the final formative proposals. Figure 1 shows an overview of the Hybrid Lab project.**

Gathering participants from disparate areas – people who work with various audiences in diverse contexts – makes it more likely that those participants will be liberated from the situated biases of their respective fields. This setup is designed to spark a search for new patterns of thought, processes that be conducive to innovative formative proposals. Several meetings and collective moments were held for sharing the consortium's experiences with potential users of the developed strategies (ME 1, 2, 3 and CONFERENCE 4).

Participants in the HYBRID Labs workshops (Learning, Teaching, Training Activities – LTTAS) were not necessarily higher education students or teachers. Groups also included professionals and amateurs from varied backgrounds. The concept of collaboration – between formal and informal learning strategies, and between academia, research and society – was central to the project ethos, and key to making powerful teaching/learning and collaborative tools for Hybrid STEAM subjects .

This final booklet (IO4) is a culmination of Hybrid projects, and a response to this pressing collective need to reframe and discard preconceptions. It aims to develop new ways to introduce hybrid formative proposals, in line with participants' interests and expectations, as expressed and shaped in the Hybrid Lab Network platform (IO1); this is the essence of the project, encompassing here more than is currently addressed on the project website.

Figure 1: Hybrid Lab Network overview



1.3 FROM STE(A)M TO HYBRID

STEM is a term used to connect **Science, Technology, Engineering, and Mathematics.** The term has traditionally been used to address education policy. STEM does not address the arts, which are added in an elaboration of the term, **STEAM**: **Science, Technology, Engineering, Arts, and Mathematics**. STEAM invites students to take thoughtful risks, engage in experiential learning, persist with problem-solving, embrace collaboration, and work creatively. It represents an integrative approach to learning, requiring connections across the syllabus, between standards, assessments and design/implementation. Moreover, teaching or assessing STEAM necessitates a minimum of two or more standards from science, technology, engineering, the arts and mathematics. It fosters inquiry, collaboration, and it emphasises process-based learning. Using and leveraging the integral qualities of the arts is essential to an authentic STEAM initiative.

At the present moment, people are adapting to fast-paced developments in technology, to economic change, and to new societal forms and structures. Today's students need to be educated with stimulating ingenuity, innovation, and openness, developing better social skills and a culture of co-creation. Students in STEAM programmes may have more experiential learning opportunities and gain a wider range of knowledge and competencies. Therefore, STEAM better prepares students for future working environments and challenges. However, STEAM has rarely been applied outside the sphere of higher education.

STEAM has become an accepted term in academia, in spite of the fact that it faces many obstacles and challenges. Indeed, it has been so strongly and perhaps defensively endorsed that it has even been thought of as a movement. But we believe that it is important to stress that STEAM does not extend to the field of **humanities**, a field which is, in our opinion, very important for gaining deeper insights and interpretations of the phenomena in question. Accordingly, HYBRID projects add humanities to the STEAM. We also recognized that the term STEAM emphasizes mathematics, which, as a branch of science, is already covered by the term science. Finally, engineering is a very important component of the field of technology. HYBRID fills in the spaces, augmenting STEAM's shortcomings to bring together diverse fields which we believe can create fruitful connections: **science, technology, arts and humanities**.

HYBRID is an approach which takes the benefits of STEAM and upgrades them by integrating new principles (using novel strategies that will be applied in different contexts and audiences), through innovative methods of learning, social interaction and creativity. HYBRID allows students to connect their learning of art practices, elements, design principles and standards, with the development of open thinking. It **uses open labs, design, art and speculative thinking, and collaboration between students, freelancers and members of the public who are involved with new learning practices. As such, HYBRID puts a broad palette of advanced learning materials in the student's own hands.**

HYBRID works with 4 Cultures and 3 Sectors of Academia, Research and Society. **Arts** include artistic, cultural and creative practices, including design thinking, art strategies and speculative methods. **Sciences** include not only the traditional natural sciences, but also more contemporary subjects such as open science, open standards, social and environmental sciences, and ethics as they intersect with bioscience. **Technology** brings new tools and methods used in rapidly changing contexts in research and education. **Humanities** contributes deeper comprehension and interpretation of today's globally interconnected world.

HYBRID can therefore be seen as a place where STEAM, augmented with humanities perspectives, has ambitions to establish open spaces and open labs, to apply design, art and speculative thinking, and to introduce experimental approaches to education. It seeks to foster care for ecological issues, and to find solutions for better ways of living in the future.

OUR STARTING POINT

From the get-go, our idea was to create optimal conditions for creating formative proposals for STEAM education. These proposals should meet the requirements of higher education institutions, not necessarily in the context of full degrees, but also within advanced training courses conferring university credits.

OUR OBJECTIVES

The HYBRID goal has been to provide **multidisciplinary education for multidisciplinary audiences**. In other words, we joined students of diverse backgrounds with professors and experts from different fields. Working together, they created a synergetic environment for sharing mindsets and skills.

THE ELEMENTS WE IDENTIFIED AS ESSENTIAL FOR SUCCESS

1. **Themes** in which participants can arrive at a common accord are very important (CRISPR is a notable theme)
2. **Time** is of the essence when attempting to develop a common language among participants, and to share experiences so that the right space can be created
3 A proper **space** for designing joint projects, and a testing space for experimenting and co-creating, speculating and ask questions
2. **A shared sessions** specifically structured for disseminating and discussing newly acquired knowledge, etc.

FROM OUR OBSERVATIONS - THE LESSONS WE LEARNED

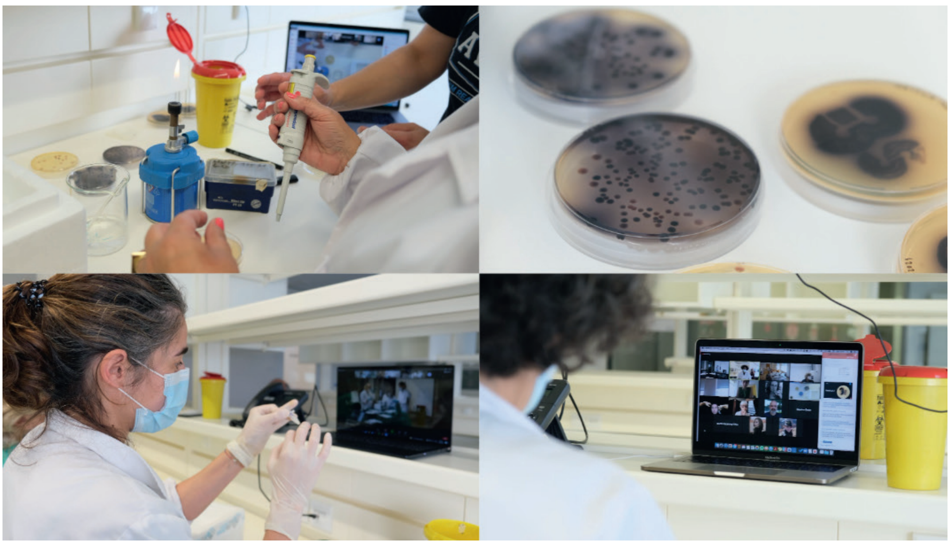
In STEAM education/teaching, or even in the implementation of multidisciplinary projects, **one area often comes to dominate and the other fields become subsidiary, deployed in service to a goal set by the dominant area.** In multidisciplinary groups, joint projects or individual accomplishments must be navigated so that all can benefit from the teaching/learning experience.

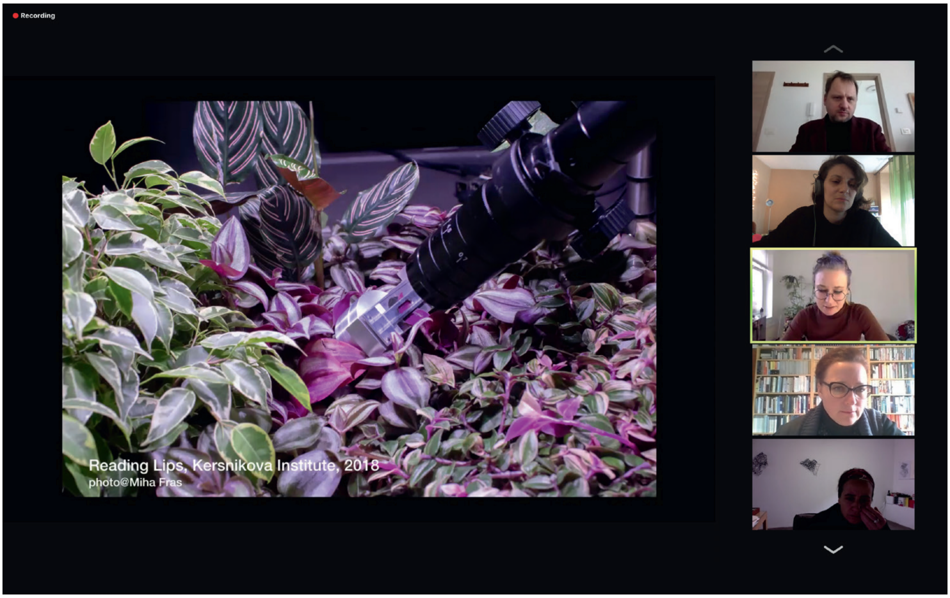
1. **Informal education and/or associative profiles – maker spaces, biohacking, or fablabs – can offer greater experience and expertise when managing multidisciplinary projects**, in which all participants are masters and apprentices at the same time. Techniques are presented by specialists in fragments: piece by piece under the same thematic framework, always in response to the collective or group project.
2. **Managing this type of multidisciplinary training therefore requires a good grasp of time, spaces, and teams**, and adaptability in relation to course contents.
3. Multidisciplinary STEAM projects need to establish **a toolbox – a set of strategies and protocols that should exceed the minimum requirements for the expected hours in training.** At the same time, a roster of professors with varied expertise should be available to teach on a range of topics, thus ensuring that no discipline overpowers others.

The work groups are to be monitored reflectively, for time management and prompt conflict resolution, to synchronize ways of thinking, and to prevent particular disciplines dominating.

HYBRID AS COMMUNITY

With its grounds in interdisciplinary and transdisciplinary working, HYBRID provides students with the knowledge, skills and understanding needed for the jobs of the future. HYBRID uses and develops spaces in which diverse disciplinary profiles and people can learn and develop different possibilities. HYBRID increases creativity and intellectual curiosity through collaboration. Its collaborative focus on group work allows individuals to learn socially, to broaden their perspectives and to extend their knowledge across STEAM fields. This is a challenging task. The core HYBRID approach involves critical thinking and radical openness, drawing together volunteering, entrepreneurship and open routes to innovation.

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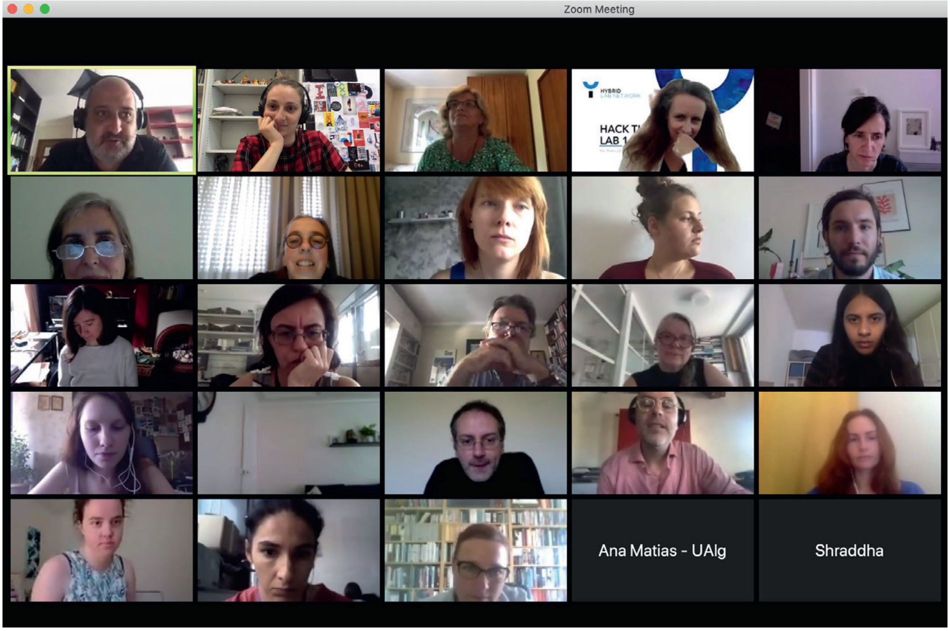
photo@Miha Fras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Ana Matias - UAlg
Shraddha

2.

PARTNERS - ACADEMIC AND NON-ACADEMIC INSTITUTIONS

HYBRID partnership consists of four institutions that are currently pioneering HYBRID approaches: two higher education institutions, a research institute and a non-academic institution with a focus on citizen relations. The partners bring a wealth of experience and foresight, enabling HYBRID to develop and adopt processes that link different disciplines and practices through education in bioscience.

➔ **Instituto de Biologia Molecular e Celular - IBMC, Portugal**
RESEARCH INSTITUTE IN BIOSCIENCE

➔ **Stichting Waag Society, Netherlands**
NON-ACADEMIC INSTITUTION WITH CALL FOCUS ON CITIZENS RELATIONS IN BIOHACKING

➔ **Alma Mater Europaea - Institutum Studiorum Humanitatis, Slovenia**
ACADEMIC INSTITUTION IN THE FIELD OF HUMANITIES

➔ **Aalto University - School of Arts, Design and Architecture, Finland**
ACADEMIC INSTITUTION REPRESENTING ARTISTIC APPROACHES

More details on the project website:
https://hybrid.i3s.up.pt/

3.

METHODOLOGY

3.1 WHAT IS A HYBRID WORKSHOP?

A Hybrid workshop is characterized by the use of integrative educational spaces for addressing the project's formulated problems. It is aimed at higher education participants from multi-disciplinary backgrounds. Hybrid workshops developed the methodologies that emerged from the experiences, observations, tools and approaches which were explored and analysed during the Hybrid Lab network project's LTTAs (Learning, Training and Teaching Activities) activities (See Figure 1), also called Hybrid Labs.

3.1.1 HOW TO DESIGN A HYBRID WORKSHOP?

When designing a Hybrid workshop the following issues need to be addressed. It is crucial to:

- **define a theme, challenge and some clear key objectives**
- **define observers** (coaches who will guide the workshop activities)
- **mix different profiles of people** (teachers, students, researchers, artists, freelancers and volunteers) with **diverse disciplinary backgrounds** on defined challenges
- **create a shared space** in which all these disciplines can feel safe in letting go of their assumptions so that they can explore new and emerging fields as they address the theme or problem
- **create, test and prototype models**
- **use different HYBRID learning methodologies, tools and practices**

The design of the workshop, setting out clear themes and objectives, and including different people and disciplines, should also introduce a focal point. **In other words, one discipline can lead the workshop from their own comfort zone, creating a space in which other disciplines** can explore and play safely in this less familiar field.

The workshop should also establish **an interpersonal space** in which participants from different disciplines can connect on a more personal level (for example, through icebreakers and games).

HYBRID workshop design also calls for the integration of prototyping models with HYBRID learning methodologies and practices such as 'lab as studio', 'design thinking with art thinking', and speculative thinking.

STEPS FOR THE CREATION OF HYBRID LABS

1. **Define a theme and goals**
   - Clear objectives
2. **Select observers**
   - Coaches who will guide and observe workshop activities
3. **Combine diverse profiles**
   - Teachers, students, researchers, artists, freelancers and volunteers
4. **Mix disciplines (4 Cultures)**
   - Science, Art, Technology and Humanities
5. **Create an interpersonal safe space**
   - Use icebreakers and fun games for the outset
6. **Create a shared safe space for all disciplines**
   - Leave room for all disciplines to explore and play
   - Draw disciplines out of their respective comfort zones so that they can build together in new fields
   - Allow disciplines remain in their comfort zones so that they can work together towards presentations
7. **Use the lab as a studio**
8. **Use design and art thinking**
9. **Use speculative thinking**
10. **Avoid shallow Hybrid (instrumentalizing disciplines)**

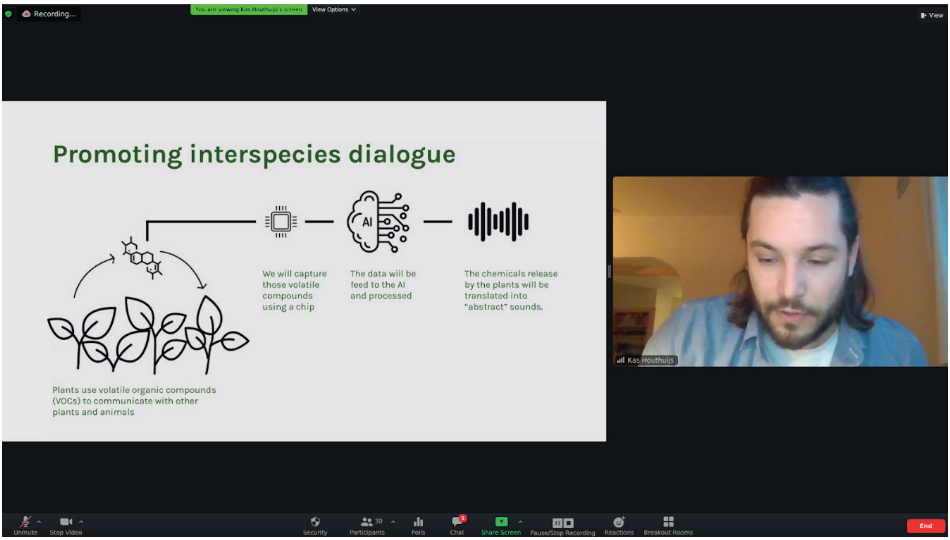
3.1.2 A SHALLOW HYBRID

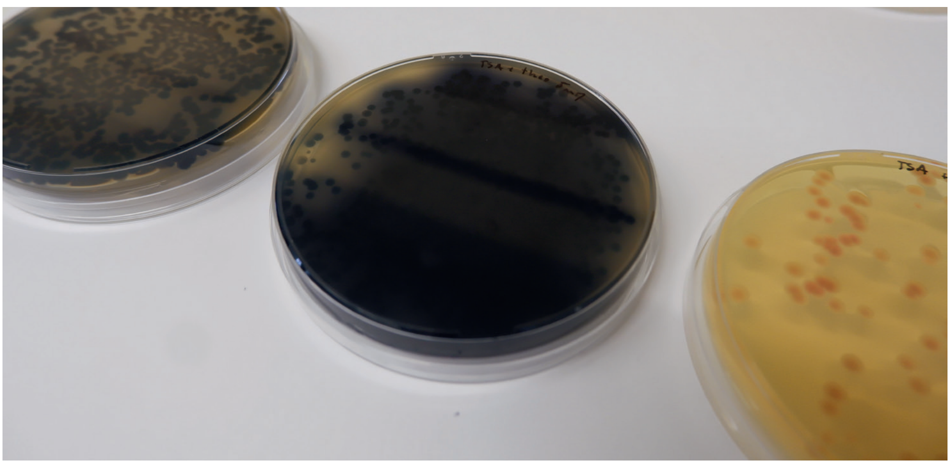
One of the main challenges in hybrid collaborations is to avoid instrumentalizing other disciplines toward a single discipline's objective. As an example: if an artist collective asks a scientist to produce a bacterial strain of a certain colour, the scientist is doing this work so that the artists can present their work. If a scientist asks the artists to make their scientific research more presentable, they are asking artists to take on the role of science communicators. None of these approaches are wrong, however, they are not true hybrid collaborations and are not a part of the hybrid workshop design.

3.1.3 IN SHORT

Note that a Hybrid workshop calls for a clear theme and set of objectives; mixed teams, disciplines and observers; and an openness between different disciplines that will enable teachers, researchers, students, professors and volunteers to work creatively in a safe space.

The space ensures that they will be able to develop and play with different proposals, approaches and ideas, venturing complex scientific, technological, ethical and environmental experiments to address the objectives of the workshop at the intersection of science, humanities, art and technologies.





3.2 LAB AS A STUDIO

Experimental setup in laboratories follows scientific principles and understanding. Art studios, meanwhile, are less structured environments which are designed to foster inspiration and creativity. HYBRID workshop assimilates the design and implementation principles of both places.

LTTA (*Learning Teaching and Training Activities*) workshops often invite practice inside the environment of a biological laboratory. This space has long been the specialized workspace of scientific experimentation, however, it has recently been rediscovered by artists as a workspace.

The emerging fields of bioart and biodesign work with living materials, biotechnologies and bioscience practices. They often **involve collaboration between artists and scientists** in matters of technological proficiency, scientific expertise, safety, environmental and ethical issues. The questions that emerged from Hybrid Lab Network workshops were questions that arose, themselves, within hybrid contexts. **For example: How do we relate to our planet and how do we relate to the many other forms of life with whom we share our planet?** New possibilities could be explored by taking a creative approach. Broad questions like this can only be answered through practice-led and mixed-group collaborations.

A hybrid lab laboratory could be a science laboratory with a studio-like approach. A hybrid lab art studio could be a laboratory (be it in engineering, biology, or technology) – or a philosophy department classroom.

3.2.1 WHAT IS A LABORATORY?

Hybrid Lab Network has been fortunate to be able to organize workshops at Instituto de Investigação e Inovação em Saúde (i3S). i3S has world class, high-tech laboratories that undertake responsible research and innovation in several areas of health. However, the purpose of this Erasmus+ project is to be able to contribute to the organization of teaching/learning sessions and short courses in higher education in many different kinds of laboratories - not only in advanced professional spaces.

The root word *laboratorium* is derived from the Latin *labor*, to work: a laboratory is a highly controlled environment for working. This understanding stems from a sense that the lab is a scientific space for research, experiment and analysis: a space in which parameters can be stabilised and findings and conclusions validated.

Drawing on experiences using laboratory settings for biohacking experimentation outside the research institute, HYBRID has set out proposals for the establishment of a simple laboratory space for biology-based STEAM experimentations. The HYBRID lab departs from laboratory conventions of technique and purpose.

3.2.1.1 LABORATORY AS A CREATIVE SPACE

The lab's potential as a creative space has recently gained attention. Art schools all over the world have labs, or are creating labs, to teach a new generation of students how to work in these spaces – Neri Oxman's MIT Media Lab is a well-known example. The new interest in laboratories derives from a desire to re-evaluate our relationship with nature, other lifeforms, and the planet as a whole. A lab is a controlled space in which other organisms can flourish, and humans can work with them.

There are some common features between scientific and creative labs: users of both types of lab will need to be trained in how to use the space; both have technical safety requirements.

However there are also several differences, especially when setting up a small biolab. For example, most scientific hardware has been designed to replicate results consistently. This makes sense in a scientific experiment, but it can require robust and expensive hardware. When using the lab as a creative space, small fluctuations in the outcome may not be material – in some forms of bio-art, they can even be desirable. It may be necessary to work with cheaper and more usable equipment from other disciplines that share goals.

3.2.1.2 CREATIVE BIOLAB - A HYBRID LABORATORY

The basic building blocks of a creative biolab (Hybrid laboratory) are:

- A space that is easily cleaned and made of non-absorbent materialsA cleaning station for materials and handwashing, and a sink with running water A working disposal system for waste
- A sterilizing area, so that unintended contamination doesn't occur. A camping gas canister and Bunsen burner can be used to sterilize materials when there is no sterilizing hood available
- A temperature-controlled space in which it is possible to grow organisms (for example, a reptile egg incubator)
- A temperature-controlled space for storing materials, such as a fridge-freezer.
- An electric cooker for heating materials

- A pressure cooker for sterilizing materials and to destroy organisms before disposing of them when work is complete

This is the essential kit for setting up a basic lab, it can be augmented with project-specific useable and materials. The basic equipment can be found for a few hundred euros, or less if second-hand. Some experiments will need more specialized equipment which can be costlier or more difficult to acquire; other projects will call for an expert team to supervise safety.

3.2.1.3 BUILDING YOUR OWN HARDWARE

The possibilities for creative engagements with a biolab extend beyond the specified goals of the experiment. Technology and hardware can also be subject to the creative process. A piece of lab equipment can be used in very different ways between creative and scientific labs: the way it is put to use will depend on the needs of the project. Artists who tinker with hardware sometimes create new uses – which can, in turn, benefit scientists.

From a creative perspective and with regards to costs management, it can be beneficial to build your own hardware. Most of the lab equipment which was made at Waag's BioHack Academy in Amsterdam is available as open-source DIY models.

3.2.2 AN EXAMPLE OF CREATIVE BIOLAB IN HYBRID

The Wetlab at the Waag is one of the creative labs participating in the Hybrid project (together with Biofilia Lab at Aalto ARTS). The Waag is a creative biolab in an early seventeenth-century building. It has been awarded the official Biosafety Level 1 lab requirement from the Dutch government and is authorised to conduct experiments with genetically modified organisms.

The Waag Futurelab has a defining principle of open-source working . It strives to ensure that the blueprints and protocols which are developed here are available for all to use under creative commons licenses.

The repository for many DIY (*Do It Yourself*) pieces of lab hardware can be found on the github page of the biohack academy (The Wetlab at the Waag). These include: Thermocycler, Spectrophotometer, Incubator, Heated Magnetic Stirrer, Electrophoresis Gelbox, Microscope, Sterile Hood and Bioreactor.

The Wetlab at the Waag also has second-hand centrifuges, microscopes and pipettes and a DIY thermocycler, a gel electrophoresis box and a spectrophotometer. This allows users to perform complex state-of-the-art experiments such as genetic modification with CRISPR-Cas9.

The Biofilia Lab – laboratory for biological arts – at Aalto University is very similar in its safety level and range of equipment, though much of the equipment here is industrial and scientific in origin. The difference is that Biofilia is set within an academic institution and therefore it is differently accessible to the public. Biofilia is primarily accessible to students and faculty from the institution.

3.2.3 IN SHORT

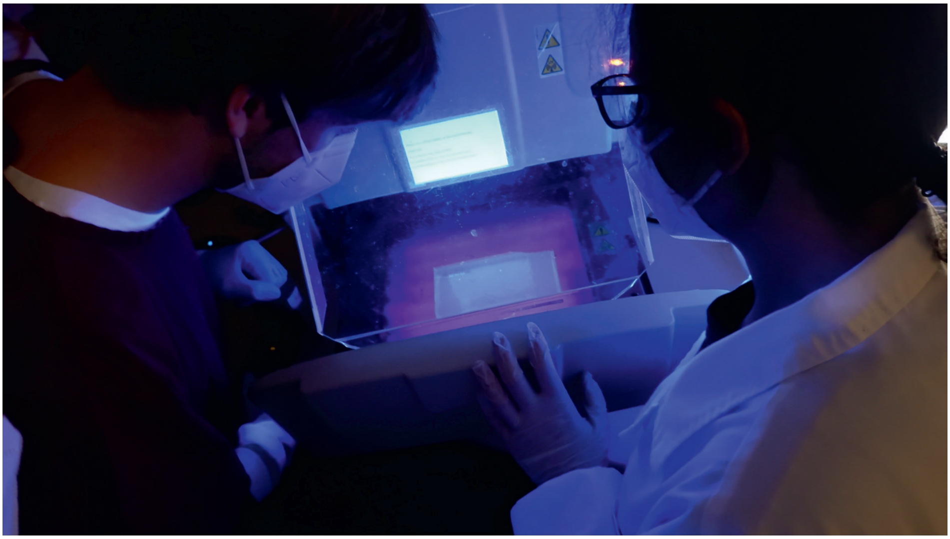
A hybrid lab laboratory could be a science laboratory with a studio-like approach. A hybrid lab art studio could be a laboratory (be it in engineering, biology, or technology) – or a philosophy department classroom.

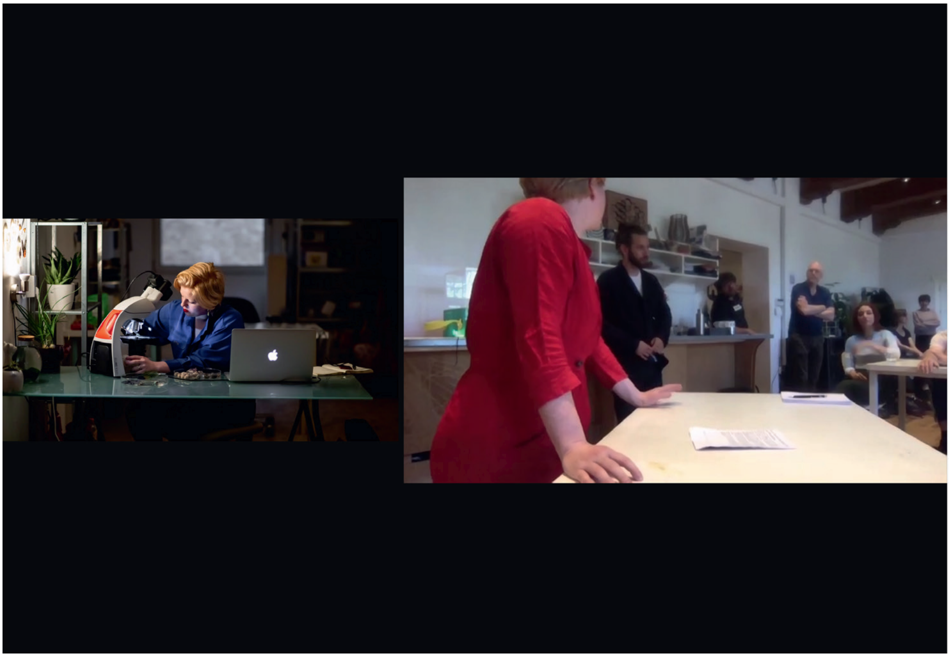
There are some important characteristics that need to be addressed when using creative biolabs for learning, training and teaching activities:

- *Protocols used in scientific settings are not sufficient for a hybrid setting and need to be implemented together with other lab-specific protocols Artists and other participants who come from non-scientific fields of expertise should briefed in advance on scientists' relevant skills and any implicit knowledge*
- *The sequence of steps in the protocols does not always aim directly toward the end goal. A 'helicopter' view of experiments needs to be providedBuilding and using DIY hardware can greatly increase the understanding of the necessary steps in the protocolsDifferences in hardware and the availability of materials can lead to vast differences in the outcomes or success rate of the experiments*

Also note that due to the scientific origin and potentially hazardous nature of the work carried out in laboratories, there are strict rules. These rules are particularly rigorous when working with genetically modified organisms. When setting up a lab as a studio, the rules can be divided into two major categories: lab safety training and rules regarding lab safety.

- *Please consult a biosafety officer when you are planning to establish a lab. When working with living organisms, especially with genetically modified organisms, be aware that different countries can have major differences in legislationPlease be mindful of the fact that you are working with living organisms, however smallDo not waste lifeforms unnecessarily*





3.3 DESIGN THINKING AND ART THINKING

Design thinking is a broad approach that has been adopted by some of the world's leading brands including Apple, Google and Samsung. Universities offer training in design thinking for students in many different subjects. Art thinking and design thinking are both incorporated into Hybrid workshop design.

3.3.1 DESIGN THINKING

Design thinking is incorporated into economic processes. It serves to improve communication between the seller and the buyer. It proposes a set of techniques for designing and solving problems, and to induce emotional responses, particularly at the point of reception. Design thinking helps conceptualize problems so that they can be approached more easily and successfully. In essence, it's an interactive process wherein participants seek to understand their users, challenge assumptions, redefine problems, and so create innovative solutions that can be prototyped and tested. Design thinking develops through different phases such as *empathizing*, *defining*, *ideating*, *prototyping* and *testing*. These phases can be carried out in parallel, and/or the process can return to a previous phase at any point in the process. Design thinking invites practitioners to reflect on everyday life. It stimulates the creation of novel solutions for improving quality of life and relations between living beings, and it fosters ecological responsibility.

3.3.2 ART THINKING

Art thinking, or artistic thinking, has become intrinsic to the making of art. It has also been seen as a novel method which can be repurposed to contribute to innovation. It has potential learning leverage if drawn into STEM teaching. In comparison with design thinking, art thinking is an approach that seeks to avoid the neoliberal commodification of art and culture. Art thinking brings forth the thinking that is associated with artists, particularly with new groups of contemporary artists whose work engages with social issues and interactions. Art thinking challenges situated knowledge and offers a changed perspective on the topics that concern contemporary societies. It involves individual experiences, rather than the mere understanding of concepts. Art thinking is not art making, but an mind-set that is foundational to creativity, and can be a valuable approach when problem-solving. It stimulates thought not only as ideas derived from previously established knowledge, but as a process for locating and approaching problems that need to be solved through innovation: thought as open-ended possibility.

3.3.3 INCORPORATING INTO HYBRID

When designing a Hybrid workshop, design thinking and art thinking can be used **to find strategies and solutions that are not initially apparent to the participants of a workshop.** They stimulate communication and diversify perspectives. They bring together different disciplines and crucially, they consider the final user. Both approaches are useful throughout the workshop, from experimental design to laboratory application, from artistic redesign to teaching and training…they help us find new ways achieve our desired goals.

Design thinking and particularly art thinking **invite participants to think outside the box.** They strive to develop new ways of thinking – ways that do not abide by dominant or prevalent problem-solving methods. They may have specific intentions to improve products, services, experiments, or processes, analysing how users interact with products to investigate the conditions in which these products really work. Design thinking and art thinking pose significant questions and challenge assumptions. It's a way to think differently and to dig deeper when problem-solving.

An artistic approach, based on constant creation, may offer a foundation for a future society: a way to look at things differently and to stimulate creative solutions. Through the artist's approach, constantly questioning and seeking for contemporary possibilities, metaphors and stories, rather than universalized and eternal truths – it may be possible to empower future citizens to face the complex issues of a fast-paced world. **Art thinking in workshops cultivates thinking in artists and stimulates questions around situated knowledge, societies' needs, and the conditions in which we might build a better future.** It can also bring innovative perspectives to design and to new technologies. Hybrid workshop uses this approach with the intention of delivering innovation, education, and experimentation. Teaching/learning strategies using artistic approaches might include leaving the laboratory or classroom to explore (for example, trips to art venues and museums); inviting speakers to deliver talks or workshops; carrying out case-studies of art projects; making prototypes; or producing art-like actions, with the intention of educating teaching/learning groups in critical thinking.

Both approaches (design thinking and art thinking) were used in the training, teaching and learning activities during Hybrid workshops that involved addressing CRISPR/Cas9 experiments and dealing with the complexities, ethics and philosophy of this gene-editing technology.

3.2.4 IN SHORT

There are some important characteristics that need to be addressed when applying these approaches:

- *Use design thinking when learning new concepts with multidisciplinary teams Use art thinking to bring a questioning approach to issues of designing and experimentation Tours, invited talks and prototypes can be components of a workshopUse creative building – 'hands-on' hypotheses and short exercises – to clear or reset participants' mindsets.*

Note that design thinking and art thinking are aspects of Hybrid workshop design which can contribute to the development of a safe space for all disciplines.

Note too that both approaches can facilitate the openness, creativity and interdisciplinarity that are key to the design of any Hybrid workshop.


PLANTS + BRIGHT ROOMS
ORGANIC FURNITURE
why work?
RAW MATERIALS AVAILABLE
other-than-humans -?
STUDY VISITS to PLACES OF INTEREST
GAMES
50% social 50% solitary
coffee
decaf
yesss!
space

3.4 SPECULATIVE THINKING

Hybrid design workshops sought to encourage speculative thinking across the arts and the sciences, and so Hybrid workshops adopted and modelled aspects of speculative thinking. There is a common perception, within and beyond the scientific community, that scientific research could be communicated more clearly and engagingly. Meanwhile, artists have been using scientific methods and tools in their practice in emerging fields such as bioart, biological arts, biotech arts, and art & science.

Artists often begin to develop their dissemination skills at an early stage in their career. However, the emerging arts/sciences fields have only recently begun to appear on higher educational curricula, and courses in these subjects are limited to a small number of institutions.

3.4.1 WHAT IS SPECULATIVE THINKING?

Scientific studies, which frequently focus on a single aspect of research, can overlook their wider contexts. This means that some potential outcomes or applications might fall away. Speculative thinking offers an imaginative technique for overcoming these issues. Speculative thinking workshops can be tailored to enhance creative skills. **Storytelling was central to the concept of speculative thinking as developed by Hybrid workshops. Interaction among heterogeneous group members also played a crucial role**. Participants from different disciplines worked together in collaboration to develop a common narrative. Social interactions and problem-solving approaches were invited in this phase, with the intention of pluralising field-specific attitudes.

3.4.2 EXAMPLES OF SPECULATIVE THINKING FOR CRISPR

During the Hybrid workshops that took the CRISPR gene-editing method as a starting point, groups were asked to envision future hypothetical scenarios in which CRISPR practices would become common in everyday life. Different narratives emerged from a scenario that imagined gene-editing technologies as fully developed and freely used. This led participants to consider the notion that new research needs nothing more than a clear societal vision in order to be carried out. In this case, speculative thinking centred on resolving environmental problems, such as the cumulation of microplastics. As these speculative futures were envisioned during the workshop, ethical challenges emerged. **For example, in imagining the development of innovative**

processes and products, it became clear that it would be dangerous to overlook the wider context of social concerns in light of the possibility that the innovation would come with unforeseen consequences.

In another exercise, groups were asked to build a free-standing tower, as tall as they could, using only spaghetti and playdough. As the exercises were carried out, single individuals tended to take the lead, and these individuals didn't gain consensus on their approach before setting out. This attitude presents a common feature of human behaviour, modelling how new phenomena can find its way into the hands of a small dominant group, thus compromising any initial idealism. In the case of important scientific discoveries such as CRISPR technology, the workshop findings identified a need for a shared decision-making system which could represent a wide spectrum of voices (including non-human agencies as well as humans). Perhaps this is the only scenario in which these technologies could foster truly positive impacts.

3.4.3 IN SHORT

Speculative thinking is an invitation to think outside the box, beyond hermetic laboratory protocols, which are sometimes considered pedantic (particularly by non-specialists). It also leads to a consideration of power, and profit-oriented realities. In doing so, it draws emphasis to ethical regulations as a necessity – the very keystone of transdisciplinary collaboration, rather than an impediment to research.

Note that speculative thinking is a key element of Hybrid educational modules because of its manifold values. It brings presentation skills, team working and dialogue. It also opens discussions about new possibilities within the sciences, involving arts and humanities perspectives in these discussions, and illuminating potential ethical problems that will arise with the research as it develops.

Note too that:

- *Speculative thinking exercises are moments in which all members of the diverse groups will engage in the same task and in subsequent discussions in which each will bring perspectives from their own backgrounds and professional experiences*
- *The ethical aspect of speculative thinking brings groups together to work towards a common goal, one that calls for participants to ask themselves what kind of world they want to inhabit.*

4.

OUR APPROACH TO HYBRID HIGHER EDUCATION

4.1 OUR INSIGHTS INTO PREPARING EDUCATIONAL HYBRID ACTIVITIES

HYBRID's approach to higher education can involve: a culture (or cultures) situating the arts and the sciences on an equal level; and group activities in joint training and exploratory workshops for staff, teachers, researchers, artists, students, invited teachers, and others.

The chart below lists the insights gained during the project.

SPACE BEYOND FRAMES - Uses the **3 SECTORS:** Academia, Research and Society - Steps out of comfort zones, disciplinary frameworks, traditions and cultural bubbles - Generates qualities and methodologies that promote new ways to learn - Creates formal and informal spaces of learning - (Re)uses open labs and open spaces	**TRANSDISCIPLINARITY** - Uses the **4 Cultures:** Science, Technology, Arts and Humanities - Avoids instrumentalizing disciplines - Explores and experiments via a driven, student-centred, and holistic approach that gives permission to fail and to feel comfortable with uncertainty about outcomes - Supports practices that are transdisciplinary and emphasize prototyping and making - Collaborates with public volunteers
COLLABORATION - Uses arts methodologies such as creative exploration, design thinking, art thinking, and speculative thinking - Fosters cooperation between academics and non-academics - Develops a cooperative and multi-modal approach - Prepares spaces in which different kinds of people can do different kinds of tasks	**PROBLEM BASED LEARNING** - Offers new ways to STEAM fields such life sciences - Introduces ethics and humanities to the fields, applied to the experiments as a prerequisite - Develops competency in critical thinking, creativity and communication, and explores how these attributes can be used to generate solutions

4.2 OUR INSIGHTS: CONTRIBUTIONS OF THE 4 CULTURES WITHIN EDUCATION

Summary of the 4 Cultures' (Science, Art, Technology and Humanities) respective contributions to Hybrid in education.

SCIENCE - Understanding of phenomena and of universal laws - Aspirations to objectivity - A hypothesis-based and result oriented process - Protocols that control variables and increase reproducibility - Experiment-based training	**ARTS** - Independent explorations - Opening of perspectives - Critical thinking - Subjective approaches - Hands-on approaches, including DIY Aesthetic outcomes - A focus on process Alternative perspectives and solutions
TECHNOLOGY - Aspirations to innovation - An orientation toward application Empirical research - Application of knowledge to practice - Usable solutions	**HUMANITIES** - In-depth interpretations - Comparison and analysis - Critical approaches - A habit of questioningOpening of perspectives - A questioning approach to science and technology - An orientation toward thinking

5.
IMPLEMENTING HYBRID

5.1 TOOLBOX INVENTORY

The Toolbox (https://hybrid.i3s.up.pt/toolbox/) developed in Hybrid covers the key stages of the learning process: investigation, discussion, experimentation and creation. The tools have been organized into seven key categories, based on their use in learning and teaching environment:

Dialogue and creativity A toolkit for interdisciplinary environments, in which it is essential to bridge the gaps between participants' perspectives and differing fields of knowledge. This toolkit will help users in promoting dialogue, thinking outside the box, and in creative exploration.
Lab work and experimental scenarios Challenging but powerful educational tools for introducing people from different backgrounds to experimental processes. This knowledge and technique will allow non-scientists to broaden their scope by discovering new paths for exploration and creativity. Meanwhile, scientists will consider how to communicate their work and rethink their practices.
Online tools Pre-existing online tools and some potential uses and applications for educational settings. The tools can include websites, online platforms and videos, or proposals for the organization of online teaching/learning.
Lectures and presentations Resources recorded at Hybrid Lab Network events, and also from other sources. Experts from many fields – artists, scientists, writers and philosophers – present their work and introduce key concepts. The lectures challenge perspectives and introduce new projects and interdisciplinary questions.
Reading list and reference list An extensive reference list of interdisciplinary resources, including books and articles on a wide range of topics, supporting varied course structures and different challenges. The list includes artists, art projects and other sources of information that could be useful for interdisciplinary exploration by staff or students.

5.2 HYBRID LEARNING - PILOT COURSES FOR THE 4 CULTURES

Hybrid Learning for the 4 Cultures uses pilot courses developed by HYBRID and implemented in bioscience. These courses work to equip participants with the ability to grasp new concepts in different subjects across the biosciences. They also create space for participants to think and experiment critically and creatively, and to act entrepreneurially, while developing and applying new ideas. The courses are designed to produce researchers, developers and 'innovation managers' who will drive scientific discovery, and who will promote and adopt new ideas in across disciplines.

Innovative teaching and learning methods were developed and tested in Hybrid pilot courses for higher education, as set out the EU action plan for higher education, which recommends the uptake of STEAM subjects through multidisciplinary programmes, and cooperation between relevant faculties and HEIs (Higher Education Institutions).

Alive Together:

An interdisciplinary community for research in human/ animal/ multispecies relationships, developed through the Hybrid Lab Network. Alive Together shares approaches to developing knowledge, and teaching/learning methods, from the arts, sciences and humanities, and emphasises building skills through interdisciplinary working methods.
http://alivetogether.i3s.up.pt/

Unboxing CRISPR:

A transdisciplinary learning pilot proposal for a course, module, or curricular unit for higher education. The purpose of the unit was to explore CRISPR-Cas9 technologies in a multidisciplinary context, involving art, design, and humanities students. The pilot was developed during Hybrid Lab Network activities and tested with students, teachers, and members of the public from different countries and backgrounds.
https://hybrid-course.i3s.up.pt/

Creative CRISPR:

An educational module for artists and members of the public who are interested in genetic engineering and want to explore CRISPR-Cas9 technologies in creative contexts. No prior knowledge of biology or laboratory experience are needed to participate. This pilot course was developed during Hybrid Lab Network activities and tested with students, teachers, and people from different countries and backgrounds.
https://creativecrispr.github.io/

Humanities on ethics of biohacking / biotechnology / engineering and innovation:

A responsible philosophical approach to considering the appeal of social normativity which takes into account different explanatory models and principles of understanding. The process involves researching the practicability, evaluation, and administration of normative standards for specified domains in which there is a risk of impingement on personal autonomy. The intention is to privilege justice in response to critical issues, and to make possible the mutual recognition of the other in a digitized social world and in the world of new biotech.
https://www.ish.si/?page_id=6551

Into the Blue:

A pilot proposal for a course, module, or curricular unit for higher education which aims to explore relationships between disciplines in the co-creation of knowledge. It was developed by Hybrid Lab Network and tested with students, teachers, and members of the public from different countries and backgrounds. We chose *the blue* as a starting point for exploring the interdisciplinarity of knowledge and relationships between art, science, technology, and humanities.
https://blue-course.i3s.up.pt/

6.

HYBRID PERSPECTIVES IN EDUCATION

6.1 TOWARDS A HYBRID MODE OF EDUCATION

6.1.1 What on earth is STEAM?

The HYBRID project began with reflections about STEAM (Science, Technology, Engineering, Arts, Mathematics) education, with a shared intention to use STEAM as an umbrella concept. However, as the project unfolded, it became clear that the terms of STEAM could not encompass all aspects of our work (See section 1.3).

For example, the fields of humanities and critical thought are usually gathered under the 'A'/Arts letter of the acronym and are therefore not independent, integral components of the term STEAM. However, we realized that the humanities were necessary to our work, for bringing critical questions, such as ethical questions, to the area of life sciences which were the central subjects of exploration.

At the final Hybrid conference in Porto (September 2022), a short discussion on the term STEAM raised the question of how to understand how to define STEAM – what it is and how it really works. Is it a movement, a method, an ideology, or something else? It became apparent that the term is both unclear and limiting. In light of these observations, and of other developments in project processes, the Hybrid Lab Network consortia chose to use an alternative vocabulary, including HYBRID and hybrid learning. This new vocabulary is less limiting than the term STEAM.

6.1.2 What are the possibilities for accessing transdisciplinarity in studies that are limited by institutional regulations?

It became clear, during transnational discussions, that some institutes offer limited options to pursue a transdisciplinary education. For example, in many countries students are not considered qualified to study towards a postgraduate science degree if they don't possess an undergraduate degree in the same field. However, in some countries (such as Finland) an arts degree is an exception in that students can enrol on arts postgraduate courses from diverse bachelor fields.

This project offers a process for bypassing national and institutional regulations so that students, teachers, and others, can gather knowledge from diverse fields. HYBRID was conducted as an extracurricular project in the participating academic institutions. Participants did not necessarily gain accreditation, but they could nonetheless learn and be exposed to other practices.

We can see that there is still room for development in the philosophy and methodology of transdisciplinary education, as we seek to create possibilities for educational exposure to other disciplines. At the final project conference, Alexandre Quintanilha, an experienced scholar, framed transdisciplinarity as a subject of experience: “you cannot teach inter/transdisciplinarity – you can only experience it.” Transdisciplinarity is not a field, but a possibility and an approach within education.

6.2 NON-ACADEMIC AND ACADEMIC INSTITUTIONAL COOPERATION

6.2.1 Space and technical resources (licensing etc.)

One of HYBRID'S main implementational challenges **was identified as the space itself** and the variable range of technical resources that are available in different places. Laboratories (science class design) are not set up for 'plastic' exercises, and ateliers/studios (arts class design) are not set up for the precise execution of scientific protocols. It was necessary to create a third zone: a space that affords the technical facilities to support multidisciplinary approaches for different types of experimentation.

6.2.2 Learn how to make some of the technology flexible

Drawing on experience, we have come to believe that maker/ biohacking/ fablabs models can and should be used to incorporate hybrid learning/teaching at accredited higher education training institutions. This would bring enhanced skills development and create opportunities for cultures to reconcile.

Maker/ biohacking/ fablabs spaces are designed to accommodate the variability and complexity of the available technologies (within their limits). Learning proposals are compartmentalized as 'drawers'; room can be made for experimentation by articulating these drawers, or by designing new drawers that are able to accommodate a new portfolio of content (thus bringing flexibility). HYBRID course proposals were designed with this segmented and integrative log frame, to offer flexibility and freedom while avoiding chaotic situations.

6.3 CHALLENGES ACROSS THE 4 CULTURES

6.3.1 Accreditation

HYBRID as a possibility and an approach within education does not currently appear on regular curricula in academia. As an approach that exposes students to interdisciplinarity and transdisciplinarity, it is, however, something that needs to be given space in academic accreditation. HYBRID gives students experience of the transdisciplinary activities that will enable them to cope with today's complex real-world challenges by equipping them with modern approaches. The project, in its aims and in its findings, established that contemporary challenges require transdisciplinary and interdisciplinary approaches.

6.3.2 Prior curricular orientation

HYBRID workshop sessions require the experimental freedom that can beget chaotic course management. Because of this, it's crucial to provide curricular orientation before work begins, thus allowing time and space for test runs on any full experimental response.

6.3.3 Oversimplification and conceptual issues

One of the main risks, when working with scientific methods, is the risk of oversimplification. For Hybrid, certain basic scientific concepts were somewhat implicit, but not necessarily apparent to interdisciplinary audiences. They needed to be explained. Because of this, Hybrid developed exercises specifically to address oversimplification in the communication of messages and knowledge. This is a challenge that cuts across interdisciplinary teaching, regardless of the educational field. When implementing workshops, it is important that the rigor of science teaching should not be sacrificed. Bewildering arts students, through complexity, quantity, or variety, as they are trained, to provoke disruptive exploration; and involving elements of disruption from the very earliest stages of the teaching/learning process, are crucial to HYBRID. Science students are more likely to struggle with the disorderly aspects of hybrid teaching/learning setups. Therefore, these hybrid setups must convey the rules very clearly from the outset. Namely, they must involve elements of scientific accuracy, and disruptive processes must be framed by rules that are fully understood and have gained participant consensus. Participants need to develop a mutual understanding of new concepts. They need to develop a shared language for their new ideas, and concurrently to build that trust that is necessary to this new, collective vocabulary.

6.3.4 Overcoming disciplinary dominance

The existence of dominant disciplines has been identified as one of the main obstacles to HYBRID exploratory teaching/learning processes, in truly transdisciplinary training contexts. Even on the common ground of HYBRID, science and technology tended to self-proclaim as superior to humanities and arts, on the basis of a narrative in which sciences and technologies are seen as foundational to modern Western societies. Interestingly, during project activities, dystopian futures prevailed when science subdued the arts and humanities; conversely, utopian futures were more likely when the latter disciplines were more influential. A scientific background prompted participants to seek pragmatic solutions when faced with a problem or challenge. However, HYBRID participant interviews also observed that Hybrid Lab Network activities which involved bringing different approaches to solve a particular problem often led to difficulties: the different approaches were simply incompatible. When this happened, people from the arts sometimes showed more interest in discussing the issue in its multiple facets – often far removed from credible scenarios – than in actively generating resolution or solutions.

7.

DISTANCE COCREATION

HYBRID LAB NETWORK was launched in the beginning of the COVID19 pandemic. Adjustments had to be quickly made, affecting mostly the Hybrid Labs that had to be transformed from hands-on face to face collaborative activities into collaborative educational online activities (hackathon style). Different collaborative models (tools, audience size, online or hybrid events) have been experimented and here are some of our findings:

- **Model 1** - a wider span of an online hackathon: it works better with a larger participation; has low costs for the event organizer; it allows to extract the potential of larger contribution to the learning/teaching activities or ideas development.
- **Model 2** – a multicentric hands-on lab workshop (hybrid event): it allows groups following the same experimental protocols in different labs around the world; more expensive, less people can be involved as proper facilities are needed and smaller groups can be in each location.

Why online hackathons and hybrid multicentric lab workshops are a good strategy? Because they allow:

- To surpass the impossibility of a face-to-face,
- To reduce travel/accommodation costs and contribute actively to the world sustainability,
- To enhance/promote multidisciplinary collaboration between teams in different parts of the world,
- To improve engagement and accelerate the speed of co-creation of innovative outputs.
- To drive disruptive innovation through the creation of multilocation environments that otherwise would not be connected and working together.

How to engage participants in online hackathons and multicentric lab workshops?

Open calls allow a selection of teams that are diverse, that have an interest and creative minds and that are eager to work together on disruptive ideas. For that, one should:

1 Gather a good team of mentors from different fields/and research areas;

2 Prepare beforehand (and test) all the collaborative online tools and materials/consumables that will be needed for hands-on;

3 Have a good IT support and Backoffice team to smooth all the urgent technical stuff;
4 Have a few overseers that jump into all groups from time to time, their role is to assure that groups are on time and to suggest adjustments to mentors;
5 Create very clear handbooks for mentors and for participants, explaining each group their roles, tools to be used and goals to achieve;
6 Have a landing page for team workgroup and organization, either synchronous or asynchronous working (there are several available, we used slack);
7 Define streaming platforms for main talks/sessions (there are several available, eg, youtube and faceboook)
8 Define the online video-platforms for synchronous group sessions (there are several available, e.g. Zoom and google meetings) and define rooms for all group sessions and for separate group work;
9 Define the online tools for chalk discussion or board ideation (there are several available, e.g. jam board, mural, miro, among others);
10 Make the synchronous daily moments shorter and use more days if needed; online events benefit from people participating from different parts of the world and time zones;

CRUCIAL TRIGGERS FOR SUCCESS:

- Create some general presentations and every-day briefings that gather all teams together online at zoom (e.g. moments in which each group makes a pitch to showcase their conclusions or status of their work);
- Define clear and sequential group assignment moments; they can be performed both in the prepared platforms, or other platforms, online or offline, depending on each group decisions;
- Have at least two mentors from different disciplines for each group of 5-10 participants: science and/or art and/or humanities - mentors are responsible for the group and its deliverables;
- Have enough time for icebreaker activities in each group (see our tools); have enough time for discussion and to overcome unforeseen difficulties.

CHALLENGES AND PRIZES

Challenge-based imagination trigger activities, symbolic trophy competition, and time limitation are motivation factors for group assignments.

BASIC RULES

The online/hybrid HYBRID LABs were a collaborative cocreation process in which all participants gave their best for the success of the team. From experience we defined these basic rules:

- Each team should have at least 5 members, excluding the mentors;
- Teams are compulsory; once one accepted to participate he/she/they are expected to participate;
- All participants and teams should generate as many ideas as possible in a short time by suppressing criticism and building upon each other's input;
- Each team should work on the given theme which might be based on the expertise of the scientific/other area mentor and should incorporate the wide range of knowledge and skills by the participants and arts /humanities/scientific mentor;
- Participants were allowed to use any kind of technology; and to recommend any kind of external resources necessary to implement the group assignment;
- All participants were expected to participate synchronously in the public/main sessions of the program and be present at the daily briefings;
- The workshops were divided into parts that have a specific challenge to be solved/filled; mentors were responsible to present the sequential challenges in each moment;
- To participate each person should have a computer with internet access and the necessary software (mainly zoom and a slack account);
- To participate, each person must sign a photo/video consent so that the recorded material may be used in later instances, namely for streaming in public sessions.

HYBRID LAB NETWORK CONFERENCE: STEAM AND THE FUTURE OF EDUCATION

Proceedings

INDEX

At a time when STEAM practices start to get attention from Higher Education (HE), the Hybrid Lab Network proposes a collaborative reflection on how STEAM might be approached and embedded in the culture of HE and non-formal adult education. Is STEAM the Educational CRISPR? Should we be tackling STEAM or HYBRID as the new educational paradigm? Does HYBRID go beyond STEAM?

The Hybrid Lab Network Conference was held in Porto, Portugal, on the 19th and 20th of September 2022. We invited scientists, artists, educators, funding agencies, policymakers, non-governmental organizations, and other interested parties in STEAM and in inter-transdisciplinary educational practices to join in a discussion about STEAM and the Future of Education. This discussion included rethinking innovation, autonomy, curricular flexibility, and collaborative and sustainable approaches to tackle the 4 Cultures (Arts, Sciences, Engineering/ Technology, Humanities) and the 3 Sectors (Academia, Research, and Society) in a post-disciplinary scenario.

During this event, the Hybrid Lab Network (an Erasmus + Higher Education project) shared its' experiences on exploratory and speculative STEAM Teaching and Learning activities in Higher Education and beyond. HYBRID explored a multidisciplinary approach to improve STEAM training, particularly in bio-sciences, including the development of didactic tools and resources to promote critical and creative thinking and innovation that will be shared in this meeting.

These proceedings are the abstracts (extended or short) selected as oral communication to the event. The communications contributed to the final discussion on the challenges pointed out by OECD's Education 2030 (also targeted by the EU agenda for Higher Education). Some of the ideas that emerged from this discussion were incorporated into the final version of Hybrid's best practices ebook.

Recorded sessions

The main sessions and round tables were recorded and are available online on Hybrid's YouTube channel.

STEAM in Higher Education – overview
Claudia Carter, Birmingham City University, UK
LINK: https://youtu.be/02AQEXQFEmk

ROUND TABLE: Sharing experiences in Hybrid Setups
Lucas Evers, Waag, Netherlands (chair)
José Bessa, i3S, Portugal
Marta Vaz Mendes, i3S, Portugal
Louise Mackenzie, Artist and Researcher, Newcastle University, UK
LINK: https://youtu.be/IPnu4bGO0TA

Lessons learned and best practices
Matej Mertik, Alma Mater Europaea, Slovenia
LINK: https://youtu.be/biQ2lWm1hHY

Biofiligree: from Design, through Engineering to Medicine
Olga Noronha, ESAD-Idea
LINK: https://youtu.be/RigNCkhakgM

ROUND TABLE: STEAM and the future of education
Laura Beloff, Aalto University, Finland (chair)
Alexandre Quintanilha, Committee for Education and Science, Portuguese Parliament, Portugal
Fátima Vieira, Vice-Rector of Universidade do Porto, Portugal
Henrique Quintino, Project Manager in Erasmus+ Nacional Agency, Higher Education Team, Portugal
LINK: https://youtu.be/T_kuaoSzkfk

CONVERSATION ABOUT: The Future of Working Citizens
Polona Tratnik, Alma Mater Europaea, Slovenia (chair)
SPECIAL GUEST: Rona van der Zander
LINK: https://youtu.be/R0ae6dHS8Nw

Communications

Disclaimer: The contents of this section are the responsibility of each author. The abstracts, extended and short, are published in their original form. The organizing committee selected abstracts that could contribute to the discussion around STEAM and education, however no content revision or proofreading was done.

A. EXTENDED ABSTRACTS

A01.

An educational approach to Computational Thinking through Arts and Creativity

JM Rodríguez[1], R García Robles[1]

[1] ASTERISM research group, University of Seville, Spain
Department of Computer Architecture and Technology

The popularization of digital and electronic devices in recent years is producing technological and social changes. In current curricula, whether formal or informal education, it is becoming common to read *Computational Thinking* as a teaching subject. The approach in the high school is potentially interesting beyond its usefulness to get a future job. Organizations such as UNESCO or the European Commission have considered this skill essential for citizens [1]. However, teaching computational thinking is likely to be approached merely as *teaching how to program computers*, losing the opportunity to experiment with its broad scientific and cultural substrate.

Creative coding is a form of computer programming whose purpose is to build something expressive beyond its functional utility. Through creative coding it is intended to address the introduction to computational thinking as a way of personal and artistic expression that is inherently linked to problem-solving skills, communication, and the development of tenacity, based mainly on discovery, experimentation with digital technologies, the exchange of experiences and inspired by various artistic and historical sources. Thanks to the versatile nature of creative coding, an integrated multidisciplinary STEAM training is possible, in which students learn to manipulate digital media in an expressive way and to acquire fluency in arts, sciences and information technologies, so that they discover a likely new approach in which "computer science is not a tool; it is a new material for expression" (MAEDA, 2004).

As an educational tool, learning creative programming matches Papert's conception of Computational Thinking (PAPERT, 1980), which defends the premise that knowing how computers reason can potentially contribute to the formation of mental processes that could ultimately even influence in the way of acquiring new knowledge, developing new ideas and generating self-confidence as rational beings, which carries a significant educational value. In addition, Wing's conception of Computational Thinking (WING, 2006) underlines the desirability of integrating computational objectives into the standard practice of traditional education, thus providing the context for the introduction of creative programming in the classroom as a way of transmitting computational thinking to students, arousing their curiosity, and building personal works based on their own exploration.

The intersection between art and code through the creation of digital elements with the computer provides the opportunity to exercise multiple areas: technical, critical, imaginative, ethical, empathic, etc. with a result usually abstract, creative, inspiring, in short, an aesthetic experience. Based on this, four pathways to approach the learning of computational thinking through creative programming are presented below, along with some pedagogical and didactic indications for their implementation.

Considering that the intellectual stimulation of students is crucial in their performance, in each of the proposed pathways the factors involved in motivation are reinforced [PINK]:

- Purpose: to find in the tasks an important, global cause, an aspiration.
- Autonomy: having freedom, decision-making capacity and participation.
- Mastery: experience improvement, achieve goals, increase skill.

Furthermore, during the sessions, it is worth paying attention that the process serves as a source of learning for the students as much as the final results, so the educational emphasis must always remain on the learning experience, fostering a growth mindset in which error is not permanent and in which learning produces fun and rewards. It is carried out through technical practices (the coding of artistic artifacts in itself) and creative practices (decision making), as well as ethical practices (giving credit to sources, assessing the impact and message of a work) and critical thinking (observing and studying works of art, to understand them and valuing the responsibility that comes with manipulating the digital world). Students will benefit from the incremental nature of programming: the user immediately perceives the consequences of an operation and can isolate, debug, modify it; similar to other artistic processes, such as painters applying a little paint and then stepping back to look at the resulting picture. It is reinforced that students, who usually give more importance to their grades than to their learning, become aware of what they are learning. This will presumably enhance their stimulation, with the positive influence of feedback from the teacher and their own classmates (NEEDLES, 2020). Concrete strategies for the teacher in implementing their educational programming with creative programming could include:

- Context and history of the discipline, the motivations and achievements of the pioneers.
- Reflection on the social and humanistic implications of the topics addressed.
- Publication of portfolios or personal diaries that reflect the progress of the students.
- Strengthening of group and community relations.
- Promotion of healthy competition between colleagues, common repositories, contests, voting, etc.
- Search for inspiration in various sources: artists, geniuses, referents, pioneers, current events, personal hobbies, controversial topics, abstract and subjective concepts, etc.
- Application of the 4 P's (RESNICK, 2017): *projects, pairs, passion, play*.

These pathways aim to promote creative stimulation. They respond to possible triggers of the creative process, inspired by combinational, exploratory and transformational forms of creativity (BODEN, 1987). The work methodology is based on learning by doing, that is, progression through short projects, and the play with art method (MUNARI, 1977) applying the fundamental principles of active pedagogy, proposing that students do by themselves, seek discover, experiment to make room for creativity to flourish. Each path begins by presenting a context and then engages students in questioning, thinking, and writing code. Students are encouraged to share their creations, to help each other and apply Feynman's theory of learning by explaining their solutions to the rest of the class. It is up to the teacher to use some practices such as deliberately showing the process of creating and debugging code, the composition of pencil sketches before coding, pair programming or open discussions, as well as choosing the programming language and environment.

Creative path through the production of analogies

The inspiration comes from imitating works that can be replicated computationally, extracting some quality in the original piece related to its identity and trying to take it to the algorithmic field.

Computational thinking skills include knowing basic commands and flows, creating fundamental shapes, possibly knowing how to apply color, coordinate systems, and introducing loops and elements of randomness when composing images or sounds.

This approach introduces students to the artworks and artists that have been inspiring for computational art and generative art, even encouraging them to dig deeper and discover more details for themselves.

- References: Frieder Nake, Paul Klee, Andy Warhol lithographs, Mondrian, etc.
- Discussion ideas: Michael Noll's experiment "Human or machine" (NOLL, 1966), art from the text-to-image models that generate images from text.

Creative path through exploration

The composition of the artistic artifact starts from simple forms, repeating patterns, modifying parameters. It aims to encourage experimentation and autonomous discovery by students. In addition to concepts related to computational thinking, aesthetic aspects such as symmetry, rhythm, scale, colour, shape control, and the balance between organic shapes and geometric shapes come into play.

- References: The geometric mosaics of the Arab and Mudejar culture, tesserae, textile patterns, musical bases. Artists like Sébastien Truchet, George Ness, Vera Molnar, Kazimir Malevich, who bring students closer to generative art.
- Discussion ideas: Authorship of the artistic work when the computer intervenes. Who is the legal artist of a work of art? Is the creator of an algorithm responsible for the actions carried out by the machine? What problems and ethical dilemmas can it cause?

Creative path through mathematics

Mathematics has often been a dominant theme in the artistic realm of computing. Geometry, curves, fractals or cellular automata can be programmed and serve as a source of creative inspiration.

- References: polygon rotations, Lissajous curves, trigonometric functions, gradients, or simple algorithms, such as the Sierpinski triangle.
- Discussion ideas: Mathematics in everyday life, in nature, in technology. Chaos theory and cellular automata also offer a wide field of debate and research with playful stimulation, for example the game of life (CONWAY, 1970).

Creative path through interaction

Interactive art makes its appearance in the avant-gardes of the early twentieth century. Works appear that require the interaction of the viewer, who ceases to be a mere observer to relate to the work.

Initially, we have the interaction that the user can provide with mouse and keyboard. The response to these events can configure different outputs on the construction site.

- References: from the variety of human-computer interfaces to performance and Op-Art, which plays with optical illusions and a spectator who actively participates by moving in front of the work.
- Discussion ideas: The Fluxus movement, current interactive art, urban interventions, video games and other interactive representations. What characteristics must a work have to be considered art? Should you be persistent? An interactive work is not persistent…or is it?

Adequate attention to diversity finds an ally in the multidisciplinary nature of the proposal. People with different skill sets are equally valuable, they can collaborate with each other, take on the role of mentor and mentee, take challenges further or create teaching material. The *low floor, high ceiling* (PAPERT,2017) approach sets the tone: all students, including the most struggling students, should find it easy to get started; while more advanced students should find no limitations. This concept can be extended with the inspiring *wide walls* metaphor (RESNICK, 2017), which refers to students being more engaged when working on projects that are personally meaningful to them.

Creative programming is a discipline that emerged organically, due to an artistic curiosity that made its way into a mathematical and engineering environment. Bringing creative programming to a classroom of young students, adolescents, restless, connected, digitalized, and at a stage when they make important decisions and question their opinions about the world, seems like a promising task. Teachers and students will discover that they can create artistic pieces of their own in relatively simple and complex ways through creative programming, and this process constitutes a learning experience in itself, with the reward of obtaining tangible results, which subtly reinforce the self-esteem and spirit of achievement.

To finalize our discussion, it is important to emphasize that in such overall educational framework, the ASTER research project is promoting STEAM vocations, with a special focus on Arts made by using digital applications.

Acknowledgements

Project "ASTER: Promoting Art-Science-Technology-Engineering Research by using collaborative methodologies and tools", financed by the European Regional Development Fund (ERDF) and the Ministry of Economic Transformation, Industry, Knowledge and Universities of the Junta de Andalucía, within the ERDF 2014-2020 Operational Program. REFERENCE: US-1381015

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A02.

Water body 1. The interface of interspecies communication, ArtSci work.

Andrea Gogova Ph.D.
Artist, independent researcher

The article is focused on the world of emotional communication through post-digital artwork body which manifests the principle of interspecies communication. The posthumanistic approach of communication, in the wider view, would change thinking about the problem of emotional understanding of interrelations of human and more than human intelligent agency. The flexible shape of experimental communication form could be manifested on/in many different interfaces. In the article is proposed water as interface medium of communication which is related to the Transient Pattern.

Earth is a planet where most processes are based on water. Water regulates climate, morphologically influence a landscape, is a medium of living processes. It is a medium of interaction of organism and mineral parts in microscopic view, between whole organisms and minerals in macroscale on the Earth, and endless interplanetary space.

Water topic from the position of artsci research (more than 'parasitically' utilization of water resources), increasing transferring information of life. In this artsci research, water body figuration is related to the possibility mediate interspecies communication to better understanding water-based life on the planet. The research comes out from model of procedural patterned communication which was based on relation of human and machine intelligent agency (Gogova and coll., 2021) and patterned cognition and communication of'Structural coupling' theory (Maturana and Varela, 1972), in which the recurrent interaction of unit and medium causes structural coupling, which is reflected in a patterned cognition and communication, and Jakob von Uexküll's umwelt theory. For Maturana and Varela water is a 'medium'. Communication then depends on intersection of agential cuts of each body of water patterns; according to Neimanis, in common space of water body (medium) of interconnected 'bodies of water' could emerge meanings or feelings in the interrelation of water body figure and water as medium? If yes, then interspecies communication will be interaction of each pattern or umwelt through dialogic membrane – 'which is water body medium', in the semiosphere. How is it possible to realize communicable water body of artwork?

Several authors proposed the importance of water as a medium of inter-connectivity between organisms (or minerals) together. According to planetary science researcher water was always as part of the formation of Earth`s mantle, but also originated from comets and asteroids, that break up into meteorites which fall on the Earth. Water as physical matter is shaped form the solid, liquid and gas materiality. Fluidity is not only one state of water matter, but formal aesthetical principal of artistic, designer, and architectural practices. The fluidity is recognized in the relation to Gilles Deleuze and Bernard Cache theory of Objectile[1], which based a theoretical background to digital artistic form or artwork body figuration. Then water body figures appear in the differentiations in the repetition processes of multiplicity of water cycles and niches, similarly, as appears meaning of sign (Derrida, 1967 – différance; Deleuze, 1994; Neimanis, 2017). According to Astrida Neimanis (2017) in differentiation are continuously unfolding embodiments as an expression of eternal return of the self-same. Water engendering difference 'was' an expression of water that 'is', and its potential 'yet-to-come'. Bodies of water as figuration was al-ready describe within ecofeminism and anticolonial thinking (Neimanis, 2017, Gaard, 2003, Armstrong, 2006...) Lucy Irigaray (1992) relates fluidity to the Fluidity is diffuse and multiple, overlapping, and inter-connected, is repetition in hydro/bio cycles and water figures acknowledged in differentiation. The dynamic fluid principle relates to the concept of perpetual intra-action, entanglement, diffraction, and agential cuts which was described by Karin Barad as 'matters agential realism' (Barad,2007). Then in differentiation is appearing meaning, also any act of observation is differencing agency and makes a "cut" between what is included and excluded. Every species has specific 'pattern' of differencing agencies. From

1 The first essay presented in this chapter, by Stephen Perrella, is a précis of end-of-millennium design theory: the Objectile is an open-ended notation which allows for infinite parametric variations; these can be directly fabricated using file-to-factory technologies, thus enabling the serial reproduction of non-identical parts, where ranges of limited variations can be mass-produced at no extra cost (Mario Carpo, Stephen Perrella,Bernard Cache 27 March 2013 https://doi.org/10.1002/9781118795811.ch10 in Topological Architecture (1998–2003).

"Objectile is an object which is not yet defined by its essential form, but becomes the pure functionality "... (Deleuze, 1988). and open it to artistic research of digital form. Fluidity as a principle of shaping architectural form was followed in nonrational geometries of interrelated architectural space and environment and the other circumstances or parameters (Last,2015).

the position of a posthuman approach, then it is possible to see water as a common equal medium of communication between all bodies of water (human, more-than-human, extra-terrestrial), which can bring equal informational agency.

The most art research which relates to interspecies communication was based on translation or transcription of many levels mediated communication principle, for example: Eduardo Kac - 'Genesis' (2000) or Špela Petrič (2018) - 'Institute for Inconspicuous Languages: Reading Lips' and so forth. Instead of relate communication to human language I propose water body as a common and direct medium of emotional, also interspecies communication of water body figures. Then understanding appearing in the differential intersection of agency of each communicative body of water and through a repetition will come to common emotional 'hydro language'.

I have used agency of emotional correlation of each actor, which in water environment constitute a manifestation and actualization of aqua language' forms. I acknowledge Water embodiments as common communicative space. In the research I focus on water in the role of the medium of emotional communication between all bodies of water human /more / than human, extra-terrestrial, both in micro and macro scale. Then cognitive pattern of each communicative bodies of water relates to its agency. The agency relates to agency of water body figures which are constituting new and reconfiguring systems in the concept of 'matters agential realism', to agents of water-based communication. This principal of shaping the matter is the process of performative-material practice which would configure figures and its transient patterns of communication to generate the vision of the artwork (Gogova, 2021). Because water in bodies is flowing in perpetual cycles of water niches, it is related to the procedural model of communication which was described by Philippe Bootz[2] Water is an essence. The essence of artwork has been related to the water body essence. Then the artwork water body is defined as an individual water body. The figure of the individual water body relates to agency of understanding (communication). According to Philippe Bootz`s model of visualization of procedural digital works is work individual body defined by essence, extensive parts and relations linked essence and extensive parts (Bootz and Laitano, 2013). Extensive parts are composed by physical real parts linked with es-

2 See procedural model of communication for example online https://mediarep.org/handle/doc/18625

sence, which are managed by agency. Extensive parts compose wider vision of artwork body[3]

The essence of artwork is recognized as individual agent which is related to the soul and the mind. My body (and the other bodies biological and technological) is a sensitive apparatus putting me in principles of global intuition of creating transcorporeal matter in the life of 'water body languages.' The performative-material practice is based on the gathering and applying data of extensive parts of artwork in the context of emotionally build interactive intermedia artwork. AI (Fluid mechanics) agents are a managing agency that introduce characteristics of the water-based world of artwork. The process relates to extensive parts of all bodies of water which relates to the manifestation and generate emotional actualization of artwork water body. The reading artwork essence is put in the middle of analytical - informative and intuitive feeling. Although the deep machine learning - flow dynamics modelling - are used to predict hydrological behavior, it is not possible to see what will be if human destroys a tiny balance of water flow. Through the work they are emotionally indrawn in the artistic message: 'We, as bodies of water, can interact in the water body holobion, we are all equal in the emotional based communication possibility and understanding our common human and more than human water-based life.

The goal of the work is to introduce the audience to data- manifestation through artistic emotional imagination, away from pure data, to take audience closer to understanding of water-based life, to equal communication with other bodies of water. The emotion relates to water-medium communication of interrelated water bodies. Applying a more intuitive concept could bring emotional understanding to each body of water and to engage audience to the environmental action.

Key words: Posthuman, water body, interface, interspecies communication

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3 Understanding to essence is put by Bootz somewhere in the middle of intuition affected by the reading body of work and analytical approach to body of work. If the audience is closer to the analytical reading of work, they are farther away from emotional feeling and vice versa (Bootz; Baldwin 2010)

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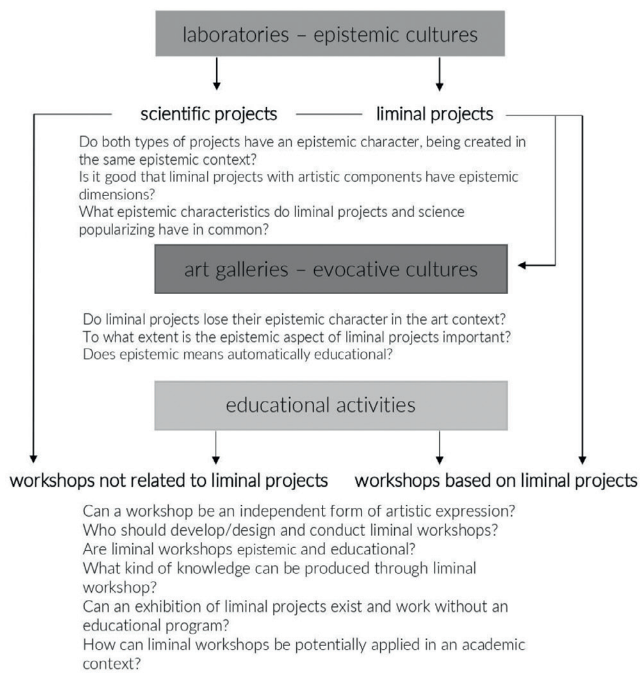
A03.

Epistemic and educational aspects of liminal projects

Karolina Żyniewicz
Artes Liberales Faculty, University of Warsaw; karolinazyniewicz@gmail.com; karolinazyniewicz.eu

As a liminal practitioner, existing "in-between", as an artist (collaborating with science), an art educator, and an academic researcher, I constantly struggle to find the best possible ways of developing all these areas of activity together. My liminal practice is an example of the STEAM approach, being funded by inter-contextual alliances. Based on my own work experiences and the content of my PhD thesis (TRANSMATTERING IN THE MAKING: Autoethnographic Analysis of Relations among Human, Post-Human, and Non-Human Liminal Beings), I created the following scheme summing up the trajectory of the liminal project's existence. In particular, I would like to reflect on the epistemic and educational aspects of liminal project creation and sharing. The created scheme contains questions that I believe are crucial for STEAM activities.



The first stage of liminal production occurs in the laboratory (in my case, biological laboratory) related to science, technology, and engineering. A laboratory is a specific place and particular sector of knowledge production. Karin Knorr Cetina, one of the most recognized scholars of Science and Technology Studies (STS), examined the laboratory as if it were a tribe, a foreign culture. She considered each kind of laboratory as an individual culture. What is common to all laboratories is that they "create and warrant knowledge" (Knorr Cetina 1999, 1). This is why Knorr Cetina proposed the notion of epistemic cultures. She did not consider the situation when a laboratory might be an area of art production. I did it in my PhD research, asking a question about the epistemic character of liminal projects created in the area of epistemic cultures. It is not even evident what is an indicator that a liminal project has epistemic features. Is it about transferring the knowledge produced by a laboratory, or maybe about moving laboratory aesthetics to a gallery? Many liminal projects do both, which also requires an explanation of the project production. It is tricky to evoke emotional reactions to something full of scientific information. From my experience, I can say that artistic audiences often complain that projects based on science and technology are not "artistic" enough. It seems evident that art produces knowledge, but its traditional methodology is different from the methodology used by epistemic cultures. Translating epistemic language and aesthetics to art's metaphoric and symbolic language is challenging. There is a thin line between art based on science and science popularizing. I would say that recognizing what art is and what science communication is based on the quality and proficiency of the mentioned translation. Art schools teach the usual methods and techniques of artistic production. I would say they teach art communication. The art audience is also trained to read artistic communicates and to expect them in artistic institutions. Visitors are confused when confronted with scientific methods and language in an art gallery. If the translation is poor, we can say about science communication rather than art. Liminal practice is basically about mastering the skill of inter-contextual translation. When the liminal project crosses the physical border between a scientific laboratory and an art gallery, the author has to decide which elements of scientific language are needed in the artistic message and which can be omitted. It happens according to the main idea of the liminal project. The message directed to the audience is essential. An art gallery is an evocative terrain where emotions and reflections are triggered. A liminal project presentation is based on a balance between reflection and information. I always find it complicated to strike the optimal balance. Working on a project in a laboratory is usually quite long and full of experiments and discoveries. It is a pity not to share all of them in the exhibition. In my case, a solution for that is academic activity channeled into writing. It requires another kind of translation to academic paper language. Still, it allows me to describe/share everything from the liminal process that is unshareable in the form of an exhibition.

The fact that liminal projects are produced in the epistemic area does not mean that they automatically have educational value. The knowledge built on the way of production has to be translated and prepared for sharing. A consistent narration is needed. Educational activity accompanying exhibitions or being run independently is essential to liminal practice. Such activity is a way of regaining the epistemic content that had to be limited to build artistic communication. Like many other liminal practitioners, a structure that I appreciate is a workshop. It usually functions as a short reconstruction of the liminal project production. A workshop related to a particular project can invite participants to learn specific scientific techniques used to produce the project. It helps the audience understand things that they missed experiencing the exhibition. In the case of liminal projects based on complicated scientific methods, like cell culturing or genetic transformation, it is hard to invite people to try the experiments by themselves, even in a laboratory. The methods are complicated and very expensive. Then, a workshop can be based on the conceptual reconstruction of the process or replacing certain experiments with others, giving participants a chance of "getting their hands wet" but being simple enough to conduct with random visitors unfamiliar with laboratory work. There is also a frequent possibility of running a workshop that is not related to a specific liminal project. A particular laboratory experiment like transforming bacteria or microscope observations can work as a starter for discussion and reflection. This kind of workshop serves as a demonstration of liminal practice when the starting point is a laboratory activity or a scientific topic, acting as an inspiration for the further translation to artistic language.

The multilevel translation, which I characterized shortly, is challenging, especially since it is a collaborative task. All contexts embodied in STEAM (Science, Technology, Engineering, Art, Math) developed their languages and methodologies, and all have representatives trained to use the specific language and methods. Translation is a challenge for people representing all the STEAM fields. Liminal projects can be seen as an essence of team translation that can succeed if all partners are equally engaged and equally respected. I would not suggest that the STEAM approach is the only possible way of knowledge production that we should develop. Still, it is a possibility to provide unique solutions for the increasingly complex reality.

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Karolina Żyniewicz is an internationally recognizable artist (2009 graduated from the Academy of Fine Arts in Łódź, Department of Visual Arts) and researcher, PhD student (Nature-Culture Transdisciplinary PhD Program at Artes Liberales Faculty, University of Warsaw). She calls herself a liminal being because her work is "in-between" art, biotechnology, humanities, and anthropology. Żyniewicz sees her liminal activity as situated knowledge production. She mainly focuses on life in its broad understanding (biological and cultural meaning). Her projects have conceptual and critical character. The main point of her PhD thesis, titled: Transmattering in the Making: Autoethnographic Analysis of Relations among Human, Post-Human, and Non-Human Limnal is multilevel relations emerging during the realization of liminal projects. She tries to put her observations, as an artist/researcher (liminal being), in the context of Science and Technology Studies (STS) and feminist humanities.

http://www.karolinazyniewicz.eu/

A04.

Sharing Space: Interdisciplinary Approaches Beyond STEM and STEAM

L Mackenzie[1]

1Hub for Biotechnology in the Built Environment – Newcastle University, UK

Louise.mackenzie@newcastle.ac.uk

STEAM in Context

The terms STEM and STEAM will be familiar to most working within a framework of hybrid or interdisciplinary practice. The origins of the terms are possibly less familiar. The term STEM was introduced in the early 21st century by the U.S. National Science Foundation (Hallinen 2019). It was not until almost ten years later that the acronym STEAM arose, defined as, "Science and Technology, interpreted through Engineering and the Arts, all based in elements of Mathematics" (Yakman 2008). As a result, STEAM is often perceived as 'adding the Arts to STEM'. This imbalance is echoed beyond the education system alone, where institutional support mechanisms and funding streams remain, for the most part, siloed and at best, skewed towards economic outcomes in science, technology and engineering. However, as Colucci-Gray et al (2019) point out, "the arts may point to the recovery of educational aims and purposes that exceed economic growth", which can be evidenced through arts relationship to public health (Perkins et al. 2021), social inclusion (Hannes 2021), community participation (Matarasso 2019), and ecology (Brown 2014).

The starting point for many STEAM projects is often, 'how do we communicate (or visually enhance) this STEM challenge?'. A more inclusive approach must surely focus on building the right questions collaboratively. This requires enabling both the skills to build the question and the context in which appropriate questions can develop. The arts and humanities are trained to critically engage with the world, to question commonly held values and to bring alternative perspectives. Practitioners within the arts embrace a broad sphere of contemporary concerns, across political, ecological and social boundaries. In doing so, they frequently develop the skills required to enable facilitation and negotiation across disciplinary boundaries. Further, arts research has demonstrated that location (or indeed dis-location) can generate transformative points of departure (Crisp, Dorsett, and Mackenzie 2022). The physical bringing together of different disciplines - quite literally the sharing of space

– unsettles and perhaps frees the mind to think beyond institutional or embedded routines.

Sharing Space: Four Practice-Led Case Studies

The following four examples briefly introduce the transformative potential of sharing space as a methodological approach to interdisciplinary practice. *Transformation – Thinking Through Making With Life* is an interdisciplinary workshop that explored the cultural implications of making transgenic bacteria. The workshop included a performative element – an invitation for participants to enter a specially designated 'Zone of Inhibition' where they could engage in a speculative conversation with the future kin of bacteria that they had genetically modified. This dis-location prompted a feeling of privacy and anonymity in participants, who expressed views not normally heard within the context of a laboratory. The resulting short film, *Zone of Inhibition*, highlights how the workshop allowed space for ethical and environmental considerations as well as the progress-oriented or economic possibilities afforded by genetic modification.

Ways of Working was a one-day interdisciplinary project primer that brought together practitioners across the arts, humanities and sciences. With a focus on process not outcome, practitioners shared working methods and explored collaborative practice in two distinct locations: the studio and the lab. In some cases, participants were familiar with one of these spaces, some were familiar with neither space. What was significant was the meeting of disciplines in both spaces. Questions and ideas that participants had brought with them at the start of the day transformed as they were able to step out of their disciplinary boundaries and 'play' with new methodologies and approaches. The relationships that formed led to a desire for collaborations to continue beyond the event itself.

Alive Together further developed the concept of sharing space for an international audience in a two-week teaching module. Formed with the support of the Hybrid Lab Network, *Alive Together* developed a teaching methodology and toolkit for interdisciplinary practice at the intersection of human/animal relationships. Critical to the success of the project teams was both time allowed for disciplines to learn each other's languages and the provision of a safe space for sharing ideas that sat outside the disciplinary frameworks of any one discipline. The two-week course resulted in three fledgling projects that actively combined disciplines in a shared research goal. Outcomes to date have been research papers and again, a desire to develop the resulting work beyond the course itself. What becomes apparent is the lack of institutional support for ongoing development of interdisciplinary projects beyond initial seed-funding stages.

BioDwelling, a project within the Hub for Biotechnology in the Built Environment (HBBE), a research group co-led by Newcastle University and Northumbria University shares space across disciplines and lay audiences. BioDwelling employs a novel and interdisciplinary collaboration between academics and lay experts through the framing of an 'extended family' which includes an intersecting set of relationships between the research community of the HBBE, a wider research network in the community and non-human actors in the environment of both the home and the HBBE's experimental home/lab space, the OME. This framing encourages researchers to build relationships with lay publics and with their research subjects (organisms such as fungi and bacteria) as a means to engender responsibility and ownership in research outcomes, linking with and extending participatory arts models of collaboration to explore kinship models of co-production. Whilst still in progress, three projects have emerged from these early interactions: *Listen With Mother?*, which explores relationships of care in relation to biological materials through the metaphor of the kombucha 'mother'; *Shit Happens!* which questions public readiness and acceptance of human waste as a circular source of energy and *OME Brew*, which uses myth, ritual and brewing practices to provoke discussion around the differences between institutional science and lay expertise.

Conclusion

In conclusion, these four examples: the individual workshop, the project primer, the teaching module and the research project, demonstrate a different kind of value than that encouraged through traditional STEM and STEAM approaches. Rather than bringing in the principles of art and design to already formed STEM projects, this approach brings arts, humanities and sciences together at the outset, working from the ground up to form project ideas together.

Rather than assuming that individuals with distinct disciplinary strengths will work in the service of each other, this approach provides time for reflection and critical questioning that strengthens the dynamics of the group and transforms the work of the individuals within it.

And rather than understanding creativity as a tool which can communicate innovation or drive economic progress, this approach focuses on providing space for creative insights to arise through interdisciplinary dialogue and exchange: insights which may themselves generate innovative outcomes, but where innovation is not intrinsically linked to the (economic) progress of one discipline.

Such exchanges allow critical questions to be raised that can lead to the transformation of ideas and practices. In this manner, ideas generated are not necessarily bound to economic goals, but are free to move beyond contemporary notions of innovation, enabling "the role of learners as human subjects, in ongoing relationship with others and the natural world" (Colucci-Gray et al. 2019). Therefore, through critical engagement across disciplines, sharing space presents the potential for forms of innovation that might just aid rather than exacerbate an already overcrowded planet.

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A05.

STEAM for Service-Learning

R Garcia-Robles[1]
1ASTERISM research group, University of Seville, Spain
Department of Computer Architecture and Technology

In the STEAM field there is a trend towards Service-Learning oriented education. But, what Service Learning is about? how can it be undertaken? and what are the implicit benefits for the educational community? At the University of Seville some Service-Learning scenarios have been designed and some of them are presented in the current paper.

The first case study is for developing Computational Thinking as well as Critical Thinking in gender equality issues. A second case study pursues the development of computational competencies focused on a double objective: to promote physical exercise and empathy among adolescents to support the recovery of young cancer survivors. A third case study is related to promoting the development of mobile applications in parallel with the development of sorority among women technologists, fostering female technological vocations and overcoming the gender digital gap. A fourth case study aims at STEAM learning through programmable electronics and robotics aligned with the SDGs, specifically with the care of the planet. A fifth case study is related to trying to foster technological vocations using robot programming in children and adolescents in a vulnerable educational community in Africa.

Those are teaching-learning experiences that seek to sensitize the educational community to real-world problems. To face with enthusiasm social challenges that promote the integral growth of people in a globalized world but attending to local objectives identified as needs in specific educational communities.

What Service Learning is about?

A good definition of Service Apprenticeship proposed by the *Center Promoter d›Aprenentatge Servei of Catalonia* [1]: "Service-learning is an educational proposal that combines learning and community service processes in a single well-articulated project where participants learn by working on real needs of the environment in order to improve it".

How can Service Learning be undertaken? Service-Learning stages

According to [2] Service-Learning can be divided into 5 stages:

1) Sketch the project
During the first stage, similar projects will be sought or if we can start from some interesting precedent. It is also necessary to determine what social need is intended to serve, as well as determine what could be offered. It should also be determined what could be learned before, during and after the execution of the project.

2) Establish relationships with the social entity to collaborate
In this phase we analyze what can be contributed jointly and reach an agreement with said entities.

3) Plan and organize the project
In this phase, the project will be defined, which can evolve over time, and the work to be carried out will also be organized. If necessary, a budget must be drawn up with the expenses that may be involved in the development of the project. In this phase, an analysis of what has been learned during the planning phase of the project could already be carried out.

4) Run the project
During this class, the start-up and development of the project must be ensured. The relationship with the environment on which it is acting must be facilitated.

5) Evaluate the project
During the last phase, the results of the performed service should be analyzed, review and record the lessons learned. Reflect thinking about the future, in the event that the project did not have an end point, analyzing whether the project carried out could continue over time hand in hand with the same group or transfer it to be continued by another group of people. Once this point is reached, it is recommended to hold a small celebration for the work done.

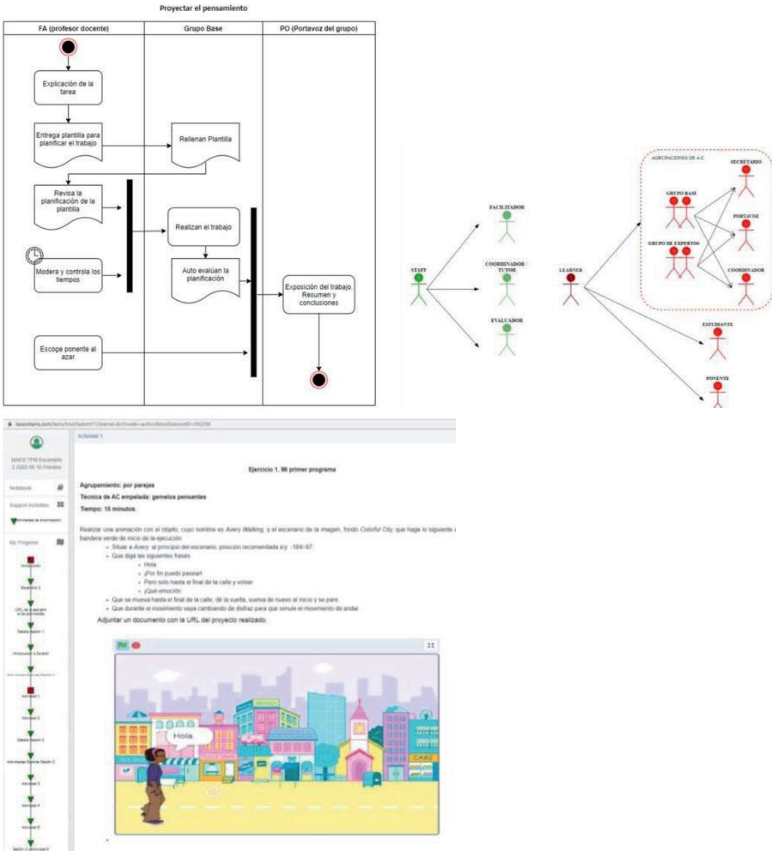

Fig 1. First case study: Unit of Learning for devoloping CT competencies and Critical Thinking in gender equality issues.

In the aforementioned case studies undertaken at the University of Seville, some university master students (MAES, master for future Secondary and Highschool education) were supervised by the author of current paper. They made final dissertations and the corresponding master thesis [3][4][5][6][7] which are available for the general public at the library of the University of Seville, and most of them are published online for the general society.

All these case studies were contextualized in the teaching of new formal education subjects in Andalusia (Spain). These are «Computation and Robotics» [8] [9] (1st, 2nd and 3rd Secondary Education), and the subject «Digital Creation and Computational Thinking» (1st Highschool).

Outcomes and conclusions

On one hand, we've got some outcomes and conclusions.

Firstly, we conclude that teaching STEAM competencies is a major challenge and incentive from the teachers› perspective. Therefore, all the case studies mentioned have been designed through Problem Based Learning (PBL) structured in several cycles. The students also predefined the learning scenario design using UML diagrams (figure 1) using the Learning Design standard [10] in order to make the workflow explicit for current and future pilot learning experiences.

Secondly, some objectives were further pursued:

1. The first objective was to give teachers the confidence to teach skills they are not so used to. Having an initial corpus of content and exercises guided by short videos makes it possible to cater for students of average ability, and at the same time to support those with special needs and those with high abilities.
2. A second objective was to give students confidence in their competence growth, allowing them to tackle problems with a certain complexity from the beginning. So, teachers offered case studies to be completed by the students.
3. A third objective was to foster creativity associated with computational thinking in children and adolescents. Therefore, collaborative learning of new projects became the best tool.

Thirdly, we consider it is essential that teachers put the emphasis on designing activities that really motivate students and that, in this way, they see a real application of what they are learning. Even go one step further and design teaching units so that students learn by doing and can be shared among the educational community.

Fourthly, in the practical cases, these didactic units are developed in which students acquire the skills that are put into play in the different subjects in a transversal way, coordinating learning between regulated subjects such as Computing and Robotics, Education for Citizenship, Physical Education, and even English if they make the application with a multilanguage layer.

Fifthly, another reflection raised on the axis of intervention in the classroom is the possibility of extrapolating the specific problem worked on to any problem that may arise among the students. For example, the problem of childhood/juvenile cancer cases could be generalized to other diseases. Thus, they are given visibility, and can serve to help the student who suffers from it in some way, as well as to raise awareness in the classroom or the center towards said problem. It is a direct way of developing solidarity, empathy and the capacity for otherness in students. In short, as Plato said, «The object of education is virtue and the desire to become a good citizen».

Sixthly, we conclude there are difficulties in awakening female ICT vocations. Fortunately, they tend to be more motivated by Service Learning as well as by creativity, so it is convenient to keep those factors in mind.

Finally, we conclude it would be very useful to have open support content for STEAM teaching aligned with advanced skills (software & hardware, robotics, IoT, AI, ...) and with the use of ICT for social objectives.

Acknowledgements

Project «ASTER: Promoting Art-Science-Technology-Engineering Research by using collaborative methodologies and tools», financed by the European Regional Development Fund (ERDF) and the Ministry of Economic Transformation, Industry, Knowledge and Universities of the Junta de Andalucía, within the ERDF 2014-2020 Operational Program. REFERENCE: US-1381015

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A06.

Biolaboratory – multidisciplinary experimentation project: an open biolab prototype

PD Ramos[1,2], F Marques[1,2], MM Lopes[1,4], JB Santos[1], F Tavares[3], MS Almeida[2], IAS Olsson[1,2]

[1] i3S – Instituto de Investigação e Inovação em Saúde, Universidade do Porto, Portugal

[2] ICBAS – Instituto de Ciências Biomédicas Abel Salazar, Universidade do Porto, Portugal

[3] FCUP – Faculdade de Ciências da Universidade do Porto, Universidade do Porto, Portugal

[4] ESE – Escola Superior de Educação, Instituto Politécnico do Porto, Portugal; (filipe.marques@ibmc.up.pt)

Biolaboratory – multidisciplinary experimentation project is a continuing training unit that has its origin in a workshop conducted in January 2020 with students from three life sciences doctoral programs at the University of Porto (U.Porto). Focusing on the theme "CRISPR & Biohacking", the session challenged these PhD students with scenarios about do-it-yourself (DIY) genetic manipulation of microorganisms of different safety levels, and asked how comfortable they would be if this would be a reality in the near future. The workshop ended with a discussion with online presence of a biohacker sharing his experience from a hacker space in Graz, Austria. The outcome of the discussion inspired our ideation of a kind of open biolab within the U.Porto ecosystem.

The curricular unit of pedagogical innovation (UC InovPed) program of U.Porto (Universidade do Porto 2017) provided the framework to further develop and realize the idea. This program supports new continuing training units provided they are a collaboration between at least two organic units of the U.Porto and have transversal aims, beyond disciplinary boundaries, This UC InovPed is a collaborative effort between two schools of U.Porto, ICBAS and FCUP, and a research institute, i3S, through the participation of seven researchers of diverse areas such as life and social sciences, communication and visual arts. The (funded) course is credited in 6 ECTS and runs for one semester. Taking place as a CURE (Course-based Undergraduate Research Experience), promoting learning through research (Bell, Eckdahl et al. 2016), allowing students to develop a small group-project that, in this case, has the particularity of integrating contributions from diverse knowledge areas, the course also sought to integrate the (regulated) informality of a community laboratory (Scheifele & Burkett 2016). *Biolaboratory* has its basis in the life sciences but includes components of social responsibility and artistic expression, aiming to emphasize the dialogue between science and society.

So far, two editions were held, in the 2020/21 and 2021/22 academic years. Students from different cycles of study (from BSc to PhD) enrolled in these two editions of the course, 13 in the first and 18 in the second. Student backgrounds include biology, ecology and environment, biochemistry, aquatic sciences, veterinary medicine, multimedia and regenerative medicine among others, with most students coming from the life sciences.

Sustainability was the main topic proposed to the students for the development of group projects, in each of the editions of the course. In 2020/21, an initial call for ideas defined biopositive fashion as the specific topic. The developed projects covered: cellulose production by microorganisms, namely kombucha biofilm; pigment degradation by soil microorganisms; production of bioleathers from food waste; raising citizens' awareness for the production and use of bioplastics, from tapioca starch or alginate. In 2021/22, no specific topic within sustainability was proposed and the students were free to come forward with their own ideas, leading to projects covering: microbial degradation of face mask polymers; science engagement for young students as way of addressing Sustainable Development Goal 1 via the decrease of school dropout; raising awareness on carbon dioxide footprint in academic institutions, through model construction and narrative building; fostering societal awareness of costs and benefits of water desalination, by exploring a model experiment for display. Table 1 summarizes the themes of group-projects developed so far in this UC InovPed.

Table 1. Main theme of the group-projects developed by the students in the two editions of *Biolaboratory – Multidisciplinary Experimentation Project*.

2020/21	**2021/22**
Microbial production of cellulose	Degradation of face masks polymers
Pigment biodegradation	Young students' engagement for science
Production of bioleathers	Awareness of carbon dioxide footprint in academic institutions
Citizens' awareness for the use of bioplastics	Societal awareness of benefits and costs of water desalination

Throughout the two editions, consistent approaches were adopted in classes, namely, ice-breaking activities, pitch training, group ideation using mind mapping and brainstorming, online or face-to-face talks, including lectures by invited speakers, as well as hand-on activities in the lab. Student participation in-class was always fostered. Figure 1 illustrates some of these moments.

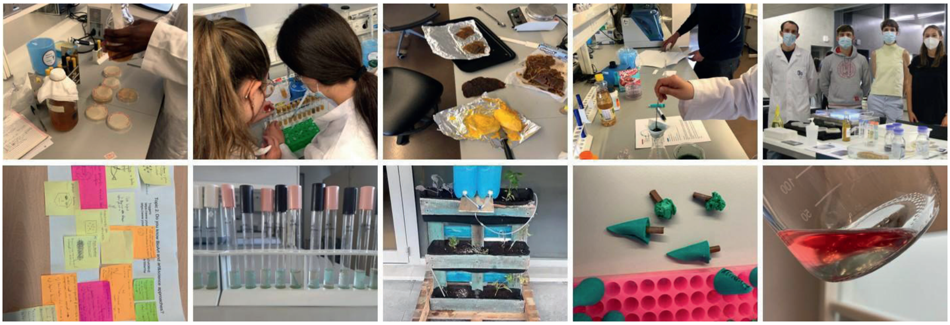

Figure 1. Illustrative images of the functioning of this UC InovPed classes and an output, the participation in a science outreach event.

Biolaboratory – multidisciplinary experimentation project is a successful initiative as shown by the students' assessment of the course. They value the multidisciplinary, practical and creative nature of the course, the opportunity to work independently in the laboratory and the fact that they are challenged, trusted and supported to develop a project from idea to prototype (Marques, Ramos et al. 2022; Ramos, Marques et al. 2022). Our own perception points in the same direction. The participation of former students in activities such as the European Researcher's Night, presenting work developed in the UC InovPed, can be highlighted as another evidence of the success of the course.

Our experience with this innovative curricular unit highlights: the importance of access to an adapted laboratory space; the importance of group tutorial sessions; the importance of practical work; the added value of multidisciplinarity; the availability of students to innovative practices. The picture that emerges for "STEAM and the future of education" puts learning through research and inquiry at the centre, as in the proposal of a connected curriculum (Fung 2017), with multiple connections – among students and teachers, across areas and out to the world...

ACKNOWLEDGMENTS – The teaching team acknowledges the technical support by Carla Oliveira and Laura Eira, ICBAS.

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A07.

STEAM approach: An experience-based report

C Ferreira[1], C Figueiredo[2], B Gabriel[3]

[1] Department of Mechanical Engineering, Centre for Mechanical Technology and Automation (TEMA), University of Aveiro, Portugal & Department of Education and Psychology, Research Centre on Didactics and Technology in the Education of Trainers (CIDTFF), University of Aveiro, Aveiro, Portugal {carlasusana@ua.pt};

[2] Department of Mechanical Engineering, Centre for Mechanical Technology and Automation (TEMA), University of Aveiro, Portugal & Research Unit on Governance, Competitiveness and Public Policies (GOVCOPP), University of Aveiro, Aveiro, Portugal {claudiafigueiredo@ua.pt};

[3] Department of Mechanical Engineering, Centre for Mechanical Technology and Automation (TEMA), University of Aveiro, Portugal {barbara.gabriel@ua.pt}

The implementation of the Bologna Process led to significant changes, both in the organization of the studies' cycles and in the traditional teaching and learning models, which were used to be more unilateral and based on the teacher transmission of knowledge (Melo, 2013). The focus now is to prepare students for the challenges of the labour market, while equipping them with the competences that will help them to cope with the uncertainties of the knowledge society. Consequently, it is necessary to develop not only the subject-based knowledge, but also instrumental, interpersonal and systemic competencies (Dias et al., 2011). For example, the *NMC Horizon Report: 2018 Higher Education Edition* points out the impacts, over the next five years, of the adoption of innovative practices and the use of technology in Higher Education. The Horizon Report presents challenges to Higher Education: i) In the short term, increased use of blended learning, through a combination of classroom and online teaching methods; and STEAM learning, which refers to the involvement of students in multi and interdisciplinary learning contexts that integrate areas of knowledge such as Science, Technology, Engineering, Arts and Mathematics (Becker et al., 2018). Zaher and Hussain (2020) defend that *"engineering design and artistic design share many aspects in common. Conceptualization, which is usually the first step in any design process takes the form of a flow chart in software engineering, which corresponds to an initial sketch for a painting"* (p. 1752).

This recent interest stems from the need to offer an education that is increasingly complete, humanistic, and aware of human behaviour in view of the social and economic uncertainties of the future, where not only science and technology will be needed, but also the arts, humanities, and social sciences (Hartley, 2017; Perales & Aróstegui, 2021). The focus on STEAM approaches seeks to respond to this need for a more integrative education in line with cultural, social, economic, technological globalization, assuming itself as transdisciplinary, interdisciplinary, multi-disciplinary, cross-disciplinary, and arts-integration (Perignat & Katz-Buonincontro, 2019). Perales and Aróstegui (2021) defines STEAM education *"(…) as one that proposes an integrated teaching of scientific-technological, artistic and, in general, humanistic competencies, with integration understood in a progressive sense that goes from interdisciplinarity to transdisciplinarity"* (p. 2). According to Zaher and Hussain (2020) STEAM approaches applied to engineering education promote active learning as they boost creativity, critical thinking, reasoning skills, aesthetic sensibilities, and appreciation, which are indispensable in the engineering profession.

In this study we report an example of good practices with a STEAM approach, between two curricular units in the areas of engineering and the humanities of a Portuguese higher education institution. Fifty-four face-to-face interviews with engineering teachers were conducted, recorded and transcribed in full, with the objective of understanding which active learning strategies they used in their classes. Teachers and students make a very positive assessment of this approach, not only in pedagogical practices, but especially in the learning process: use of collaborative learning approaches, involving students in learning activities in pairs or in groups, and also at the level of teachers› work, through their involvement in groups of interdisciplinary work and teaching; learning in which the student assumes the role of creator, through the development of learning activities that lead them to produce and edit, for example, educational resources. According to the interviewee, this initiative came from the initiative of the two teachers, and they know many of these cases. Although this type of initiatives represents isolated actions (Oliveira et al., 2009; Pinho-Lopes et al., 2009; Teixeira-Dias et al., 2009) that need a deeper understanding and a more elaborated and extensible study, namely in terms of evaluation and monitoring processes. The data reveal that while the STEAM approach does not yet have the scope that would be desirable, it is often dependent on isolated initiatives by faculty or groups of faculties within the institution. The rethinking of how higher education institutions works, which is related to the innovative approaches to learning; to the use of methods that foster more active learning experiences both inside and outside the classroom (e.g., through project-based learning, problem-based learning, learning based on research, among others); teacher training is one example.

Promoting authentic learning experiences that connect students to real-world challenges is the first step, but still, it isn't widespread among institutions. But adopting a STEAM approach requires a careful design to also reflect the technical part and the assessment for example. In addition, the real challenge might be the teachers' profile, and resistance to change. However, more and more teachers use active approaches, it turns out that they should be more systematic and probably more consolidated at the curriculum level.

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Acknowledgments

This work was partially supported by FCT grant EXPL/CED-EDG/1009/2021.

A08.

Transdisciplinary Strategies for Designing Future-Makers Through STEAM and Beyond

Alexis Story Crawshaw
Interdisciplinary Studies in Liberal Arts, California Polytechnic State University, San Luis Obispo; CICM-EA 1572, Université Paris 8; alexis@mat.ucsb.edu

This presentation discusses transdisciplinary strategies that complement STEAM and related models toward an educational design that explicitly aims to benefit culture and society. This objective is served through framing students as future-makers: shapers of their world. Speaking from the transdisciplinary field of the new media arts (computational arts), we examine how our strategies may support future ideation, making, and design as a societal praxis that begins in the classroom. Such future-based practice is further grounded in the practices of worldmaking (Willis & Anderson, 2013), speculative design (Dunne & Raby, 2013), fiction design (Candy, 2010), critical making (Ratto & Hertz, 2019), and critical design (Ratto & Hertz, 2019), as well as theories of utopia (Levitas, 2013). We discuss several ways in which we have applied this approach in UC Santa Barbara undergraduate education through the novel Mediated World course series, structured by the THEMAS (STEAM + creative Humanities) model, building off doctoral research on this topic.

Our transdisciplinary strategies entail the integration of certain fundamental cross-threads into multi- or inter-disciplinary models such as STEAM. These threads are themselves inter-related and include cultural, creative, cognitive, causal, and computational literacies. By literacy here, we mean the dual ability to both analyze and enact (through making) in a given domain. More broadly, we promote a theory and practice-based approach to these threads and to each STEAM component (e.g. the theory of engineering and its first-hand practice). Regarding the relevant literacies in our proposal, many concern the notion of a situated context: a collection of factors that include the physical morphology of our bodies (and its sensorimotor capacities), culture (including tools, conventions, language, and other artifacts), as well as the physical environment (natural and cultural).

Regarding the definitions of our aforementioned literacies, cultural literacy entails contextually situated values and meanings that shape action; creative literacy pertains to how novelty is defined and generated with respect to a situated context; cognitive literacy entails how our actions and ourselves are shaped by our situated contexts; causal literacy involves contextual probabilities as well as the shape and strength of relationships among events and entities; and lastly, computational literacy promotes the formalization of relationships among data using the computational platform, including skills such as algorithmic scripting and rapid prototyping. Collectively, these threads help us to predict, model, and design actions and trends through the artifacts we create and to be conscious of the values, meanings, and other consequences they may reinforce.

Taken together, our literacies provide insights into context and causal relationships with respect to culture and society, and they provide us with the abilities to explore them creatively, through making via computational tools. We combine and compress these literacies into a single notion of computational paideia (Crawshaw, 2022), borrowing from the ancient Greek notion of education, which entailed a disciplinarily holistic approach with a civic aim.

Through this approach, we explore how we can leverage the computational platform in STEAM-based contexts to model complex thought experiments, conduct original research, practice creative problem-solving, and produce real-world cultural artifacts. A major component of this approach uses fictional worldmaking as creative relief to abstract real-world issues and conditions. This helps us to sandbox and ponder causal cultural relationships in fictional environments to support creative problem-solving when designing for the real-world. Importantly, these collective activities promote designing with critical intention toward desired futures, toward collective wellbeing. In this way, an idea of utopia can be made operational, as a process that is co-authored through the incremental critical making of the next generations. As such, we empower students as agents of their own shared futures.

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B. SHORT ABSTRACTS

B01.

Creating Boxes for Drone Delivery: An Engineering Design Process experience in Initial Teacher Education

Bento Cavadas[1,2], Neusa Branco[1,3]

[1] Polytechnic Institute of Santarém / School of Education, Portugal;

[2] CeiED –Lusófona University, Portugal;

[3] Polo Digital Literacy and Social Inclusion, CIAC, Algarve University;
bento.cavadas@ese.ipsantarem.pt

Drone-based learning is an emergent field regarding educational technologies. Using drones, students will have the opportunity to empower their creativity and problem-solving skills, from primary level to higher education, and therefore be better prepared to face the challenges of the labour market (Bai et al., 2021). Furthermore, drones are powerful teaching tools because they can naturally engage students and incorporate a large spectrum of STEAM knowledge and skills (Bai et al., 2021; Tezza et al., 2020). Moreover, the teachers' opinion of drone usage as an educational technology is favourable (Ng & Cheng, 2019; Sattar et al., 2017).

The drone-based learning activity "Drone delivery" was based on the previous work of Cavadas and Topçu (2022), and its aim is to explore the use of drones for package delivery. This activity was proposed by a science teacher educator and a mathematics teacher educator to preservice teachers (PSTs) of science and mathematics of a Portuguese initial teacher education institution. The PSTs, organized in pairs, implemented Engineering Design Process (EDP) cycles to create a box to transport objects using a drone. Their work was carried out in an innovative learning environment, the CreativeLab_Sci&Math® (Cavadas et al., 2019). To support their work, PSTs used a guide created by the teacher educators and structured according the EDP, following the steps suggested by NASA (2018): Ask, Imagine, Plan, Create, Experiment (Test) and Improve. Data from PSTs' productions was collected, and some steps of the PSTs' work were recorded on video. The box had the following constraints: it should be strong enough to transport the object without damaging it and should have the lowest possible cost, considering the materials proposed in the guide and their cost. A grabber was accoupled to the drone to transport the package.

The results show that the "Imagine" step provided a moment of discussion between the PSTs of each pair, about their options on the best design for the box, considering the initial constraints. After achieving a consensus, in the "Plan" step, the PSTs carefully planned the box design and calculated the materials cost, making continuous improvements during this process. Then, in the "Create" step, PSTs worked together to construct the planned box. Following this step, they placed the object inside the box and transported it using the drone, in the "Test" step. The aim was to move the drone with the package from a starting point to an ending point, in a 10-meters path, without any damage to the object carried in the box. The PSTs analysed the drone's behaviour during the flight and if the box design was suitable for successful transport. Finally, in the "Improve" step, they identified upgrades to the box design and opportunities of cost reduction, to subsequently develop another EDP cycle. The video data from this step showed that PSTs informed their choices based on knowledge acquired in the previous EDP steps.

During this drone-based learning experience it was noticed that the PSTs mobilized their critical thinking, communication, collaboration, and creativity skills, which are the 4Cs of 21st century learning & innovation skills. Moreover, this activity allowed PSTs to contact with an innovative educational approach – drone-based learning -, improving their pedagogical content knowledge relating with STEAM education.

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B02.

Full STEAM ahead: reshaping initial teacher training

PC Rodrigues[1,2], R Teles[1], A Pinto, D Mascarenhas[1,2], AP Barbot[1,4], JB Lopes[3,4]

[1] ESE-PPorto – Escola Superior de Educação, Instituto Politécnico do Porto, Portugal;

[2] inED – Centro de Investigação e Inovação em Educação, Instituto Politécnico do Porto, Portugal;

[3] UTAD – Escola de Ciências e Tecnologia, Universidade de Trás-os-Montes e Alto Douro, Portugal;

[4] CIDTFF – Centro de Investigação em Didática e Tecnologia na Formação de Formadores, Universidade de Aveiro, Portugal; pedrorodrigues@ese.ipp.pt

Nowadays, integrated curricular methodologies have worldwide become a major educational focus, particularly those based incorporating Science, Technology, Engineering, Arts, and Mathematics (STEAM) and Project-based Learning approaches (Huang et al., 2020; Kim & Bolger, 2017; Marín-Marín et al. 2021; Perignat & Katz-Buonincontro, 2019). Also in Portugal, in recent years, the Ministry of Education released several regulatory documents that highlight the importance of stimulating, since early ages, multidisciplinary competencies, creativity and computational thinking skills. These documents constitute the matrix that guides decision-making within the scope of curriculum development, consistent with the vision of the future defined as relevant to 21st century Portuguese students (Couto & Campos, 2018; DGE, 2018; Pedro et al. 2017).

Thus, the integration of technology into the pedagogical content knowledge of future science and mathematics teachers is a key aspect to promote their self-efficacy (Chai, Ling Koh, Tsai, & Lee Wee Tan, 2011; Jang & Chen, 2010; Koh & Chai, 2014). This change in mentality is fundamental, since in recent years, a growing number of studies suggest that there is a reduced integration of technology in the classroom context, particularly in an effective way, that generates significant apprenticeships (Hennessy et al., 2007; Hennessy, Harrison, & Wamakote, 2010; Hennessy, Ruthven, & Brindley, 2005; Petko, 2012; Tallvid, 2016; Zhao & Frank, 2003). It is important to invest on initial teacher training as a vehicle for paradigm shift, with a replicator effect over the years.

In the current teaching context, there is workspace for teachers to produce their own pedagogical tools from accessible technological artifacts (redesigning them or identifying different practices or uses), which can lead to the conceptualization of more effective didactic sequences (Ruthven, Laborde, Leach, & Tiberghien, 2009) and more fun and motivating mediation processes for students. However, as mentioned earlier, the lack of financial resources and insufficient technical support are two of the most mentioned constraints regarding the integration of technology in teaching by teachers.

The use of low-cost, versatile, and easily accessible devices for students and teachers seems to be the most obvious solution to tackle these problems. There are several technological resources that are low-cost, open-source, environmentally interactive and user-friendly devices, that can be easily customized as teaching tools. Microcontrollers (eg. Arduino and micro:bit) and peripheric sensors, 3D printers, laser-cut machines and educational robotics kits.

This way, the training of pre-service mathematics and science teachers, carried out in the School of Education of the Polytechnic Institute of Porto (ESE-P.Porto), aims to ensure that these future professionals are equipped with the ability to develop new STEAM teaching strategies, with an effective integration of the previously mentioned technological resources. This implies an adequate use of devices, in a way that makes it possible to use them as pedagogical tools that enhance epistemic practices and computational thinking. In this talk, we will present several examples of STEAM approaches being implemented in curricular units of the *Master in Teaching in the 1st Cycle of Basic Education and Mathematics and Natural Sciences in the 2nd Cycle of Basic Education*.

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B03.

Odor mapping and citizen science to foster out-of-the box thinking

M Escarrabill[1], I Fernández[1], M Hernández[1], E Sangrà[1], J Burbano[1], R Arias[1]

[1] SfC - Science for Change, Spain; (mar.escarrabill@scienceforchange.eu)

Humans are equipped with the best possible sensor to measure odors: our own noses. OdourCollect is a free app that allows citizens to gather odor observations in real and space-time generating collaborative odor maps. The data generated - based on a participatory and inclusive process [1] - informs public authorities for odor monitoring and contributes to the creation of new evidence-based regulations, so that society as a whole can benefit.

Odor mapping and odor perception data analysis have a huge STEAM education dimension. Science for Change put it into action in the programme "OdourCollect: Citizen science in intergenerational and cross-cultural learning scenarios", developed in 2021-2022 with the collaboration of the Spanish Foundation for Science and Technology - Ministry of Science and Innovation. The program focuses on the educational benefits of neighborhoods' odor mapping by bridging the areas of Art, Science, Technology and Humanities. High School students explored the science of odors, mapped the odors of their neighborhood, analyzed the odor perceptions reported with the help of experts and visualized the results of their investigations through a wide range of techniques. After this creative exploration we wanted other neighbors to interact with students' discoveries. Public libraries - as vital community centers that offer learning opportunities and as instruments to co-create new knowledge [2] - became the perfect place for students to share their knowledge and the ideal framework to conduct community reflections regarding odor, local memories and city transformation. Thus, students shared their outcomes - via multiple formats - in the public library and users enriched the data obtained by sharing their own odor local memories and their odor nuisances through collaborative maps.

Odor mapping created an open agora in which the critical, creative and caring modes of thinking, described by the philosopher Matthew Lipman [3], emerged. Students put into practice critical thinking by categorizing smells, exploring the scientific method and analyzing all the data reported. Creative thinking was exercised by exploring out-of-the-box visualization ways to share scientific results to trigger reflections among library users. Lastly, caring thinking was exercised by exploring the links of odors with the community wellbeing and reflecting on the socio-environmental impacts of odor pollution.

Acknowledgments

The OdourCollect educational program could not have been possible without the program "Citizen Science in Schools" organized by the Citizen Science Office and the Education Consortium of Barcelona and the involvement and active participation during all the phases of all the citizen scientists from the schools Sagrada Família and Virolai School from Barcelona. All the educational activities that we are developing in a wide range of learning scenarios (such as schools, libraries and museums) are possible due to the collaboration with the Spanish Foundation for Science and Technology - Ministry of Science and Innovation.

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B04.

Food and Globalization: Let's make food more sustainable

Elisa Manero Rodrigues
Agrupamento de Escola Padre Bartolomeu de Gusmão Lisbon, Portugal;
(elisa-rodrigues@e-josefadeobidos.edu.pt)

This communication aims to present and discuss the practices proposed in the project "Food and Globalization: Let's make food sustainable", an interdisciplinary project to be implemented in the year 2022/2023.

Teachers are increasingly called upon to prepare children and young people to cope with the changes (economic, environmental and social) that are emerging. To this end, it is increasingly important to place students in active roles in their learning. The promotion of learning that covers the competences foreseen in the "Profile of School Leavers" requires rethinking the pedagogical and didactic approaches, diversifying the pedagogical and assessment methods. In the same vein, the Decree-Law No. 55/2018, of July 6, which grants "Autonomy and Curricular Flexibility" to primary and secondary schools, proposed a bet on the development of teaching and learning scenarios that privilege the active role of the student. The interdisciplinary project that we will present will be implemented in the school year 2022/2023 , and it is a proposal that can be worked in the disciplinary areas of Science, Geography, History and Mathematics and with the support of foreign languages.

The Project will be developed in virtual learning environments and the collaborative learning tool used will be Padlet and classroom. The Project objectives: To develop collaborative work; To involve students in active learning; To apply knowledge acquired in the development of a project; To provide tools and opportunities for students to apply their knowledge in the different subject areas; The skills to be achieved: Rethinking eating habits; Rethinking ways of cooking Rethinking ways of buying food and consuming it (Preferring local, seasonal food,) - Participating in awareness-raising actions on the impacts of human activities on climate change; Participating in awareness-raising actions in the community on the benefits of a sustainable diet. - As final outcomes: engaging students in collaborative learning groups to explore curriculum subjects and themes; promoting inclusion; improving language proficiency in English and French; enhancing critical thinking and creativity; studying the cultural and religious diversity of countries; and promoting self-esteem and social recognition. The Project will be supported by the Health Education Project.

Keywords: Sustainable food; collaborative work; interdisciplinary project;

B05.

FeLT-Futures of Living Technologies- artistic research with a future in education?

Kristin Bergaust[1]

[1] Faculty of Technology, Art and Design, OsloMet- Oslo Metropolitan University, Norway;

FeLT, Futures of Living Technologies, started as a three year project in October 2020, funded by Norwegian Artistic Research Program, just as we were facing a second pandemic lock-down in Norway. Built on earlier exchanges among colleagues and transdisciplinary project work with students on master level, the three-year artistic research project encompassed hiring a PhD fellow and a filling a two-year postdoc position to enhance artistic research in a transdisciplinary field of art, AI and robotics as well as scholarly reflections based in humanities. *FeLT* engages in the relations and intersections that occur between human beings, living organisms, environments and machines, relations that might evoke a sense of the uncanny. Following artistic sensibilities and concerns, artistic methods can provide entrance points that open new questions and speculation in artistic and public discourse. Fast advancement in life-sciences and life-technologies heightens the importance of moving beyond dichotomies: the locked discourses that on one end create unreflected technophilia and on the other a standstill of technophobia. We strive for diversity, addressing complex issues in complex manners, while not looking for unified aesthetics or styles. However, framing the work in an ecological discourse has been a main driver and common denomination for all participants.

The *FeLT* project emerged from the work of individuals who invested their time and research interests for art and science, embodied through practices of contemporary art, humanities, computer science, human-computer interaction, neuroscience and experimental pedagogy.

Three tracks of research are identified within FeLT:

Making with: multispecies communication and co-creation Practices of communication and co-creation with living organisms – such as microorganisms, plants or animals – might involve working with technologically complex systems as well as agriculture or indigenous knowledges and traditions.

Living technologies: living environments, humans, machines, intelligence, life and emotions, including how complex structures and functions of living organisms have entered the hybrid and synthetic technologies.

Sensorium: how we experience, interpret and develop applied aesthetics today. How can the sensorium as an expanded aesthetics provide new modalities for connecting with natural environments?

FeLT started from educational activities in the first place and students have always been part of our activities. Now, a new round of critical questioning is needed: How can we undertake the next step from an artistic transdisciplinary research environment to enter an educational reality and institutional framework? What can our contribution be to different levels of education and to different professional trajectories? What possible educational needs can be identified for the future of such trajectories and levels? Could we develop education to change the institution?

Weblink: https://feltproject.no

B06.

A Transdisciplinary Education Proposal Based on Integrating 3D Information Production and Visualization Technologies and Sciences

JF Franco[1,2,3], RS Leote[2]

[1] Cátedra Alfredo Bosi de Educação Básica - Instituto de Estudos Avançados da Universidade de São Paulo – IEA/USP, Brasil;

[2] Grupo Internacional e Interinstitucional de Pesquisa em Arte, Ciência e Tecnologia – Instituto de Artes, Universidade Estadual Júlio de Mesquita Filho – GIIP/IA/UNESP, Brasil;

[3] Escola de Ensino Fundamental Ernani Silva Bruno – Secretaria Municipal de Educação – Prefeitura Municipal de São Paulo - ESB/SME/PMSP, Brasil

Enhancing individuals' transdisciplinary knowledge skills and carrying out multidisciplinary approaches by using digital tools as a form for teaching/ learning at high education and beyond have been challenges (IEA-USP, 2022; HYBRID, 2022). This proposal and prototypes have served for reducing them, by applying the concept of computational action (CA) as a way for empowering educators and students, via instigating ones' technical and cognitive skills related to coding literacy, by connecting concepts and practices of fields such as Linguistic, Education and Computer Science (TISSENBAUM et al, 2019). CA has inspired educative computational practices for acquiring and using principles of interactive computing techniques and transdisciplinary knowledge, in a multi-modal and multicultural integrated mood. These moods, knowledge and techniques have been applied for building the cyberspace infrastructure (ANDERS, 1999), and domains such as three-dimensional (3D) computer graphics programming (CGP) for visual communication (CUNNINGHAM, 2007), information visualization and virtual reality (VR) technologies (CHEN, 2006; DIAMANDIS, 2018). 3DCGP and information production and visualization domains plus their possibilities for creating 3DVR simulations and virtual worlds or metaverses (DÍAZ et al, 2020; HAVELE, 2022; WEB3D CONSORTIUM, 2022) have served for combining multicultural and multidisciplinary knowledge related to (math, geometry, languages, history, geography, mathematics, analogue and digital technologies, arts, sciences). This type combination has stimulated ones' complex thinking and flexible mental operations for identifying and understanding how the 4 Cultures (Arts, Sciences, Engineering/ Technology, Humanities) integration with transdisciplinary knowledge can support STEAM (Science, Technology, Engineering, Arts and Mathematics) education. Pedagogical experimental computing practices based on applying Web3DVR technologies can and have been effective for stimulating accessible STEAM education. It includes inspiring subjects' technical, cognitive skills and knowledge improvements for dealing with digital, traditional, spatial and visual literacies through hands on real time 3DCGP and Web3D-based information visualization tools, rising participatory, co-creative, collaborative and sustainable lifelong education and professional developments at K-12 and higher education levels (FRANCO, 2020; 2022; DA SILVA et all, 2022). Sharing educative computing practices (ECPs), based on applying transdisciplinary knowledge and Web3DVR-based technologies integration, has brought about individuals' conscious use of techniques (FREIRE, 2011) referent to Informatics for All concept and practices (EUROPEAN COMMISSION, 2022). ECPs have contributed for achieving Sustainable Development Goals as (SDGs 4 and 5) supported by United Nations Development Program (UNDP, 2022), prototyping and reflecting about accessible tools and learning activities that can support the implementation of an 'Interdisciplinary Sciences Graduation Project' – Mathematics, Learning Sciences, Natural Sciences, Languages- (IEA-USP, 2022) and implementing the recommended practices of Brazilian 'Base Nacional Comum Curricular' (BNCC) at K-12 levels (BRAZIL, 2018). It includes investigating how to utilize emerging Web3DVR technologies for teaching/learning visual arts at higher education, basic education and beyond, with support of the convergence among art, science and technology (GIIP, 2022; GONÇALVES, et al. 2022; EDGES, 2022) and cultural studies about stimulating individuals' transdisciplinary language/linguistic and communication development (HANNA, 2015).

B07.

STEAM Skills Mountain Knowledge Campus - Mountain Alliance for Knowledge and Co-Creation

CC Costa[1], VA Ferro-Lebres[2], LM Santos Pais[3], OI Afonso Rodrigues[4], AA Gomes Alves[5], TMC Santos Barbosa[6]

[1] (carlos.costa@ipb.pt), Instituto Politecnico de Bragança, Portugal;

[2] (vferrolebres@ipb.pt), Instituto Politecnico de Bragança, Portugal;

[3] (pais@ipb.pt), Instituto Politecnico de Bragança, Portugal;

[4] (orlando@ipb.pt), Instituto Politecnico de Bragança, Portugal;

[5] (albano@ipb.pt), Instituto Politecnico de Bragança, Portugal;

[6] (barbosa@ipb.pt), Instituto Politecnico de Bragança, Portugal

The Polytechnic Institute of Bragança (IPB) STEAM Skills Mountain Knowledge Campus - Mountain Alliance for Knowledge and Co-Creation is a project/ vision deeply connected with Trás-os-Montes Region. A typically Mediterranean mountain region, neighbouring Spain, with a low population density and with exceptional environmental values. This unique place has four Natural Parks and two UNESCO Biosphere reserves, which expels its environmental value. This mountain atmosphere also generates an inimitable opportunity to prepare STEAM education and design thinking fundamental training for change. The artificial ecology paradigm needs a transference moving scenario that purpose a strong shift in education strongly pressured by climate change and sustainable goals. IPB is a world reference in mountain research, particularly in natural products applied to food. Is fostering a deepen specialization, gaining a worldwide relevance in the qualification of young people and in the requalification of the active population. Closed and inspired by the mountain, the project empowers these new skills for the new labour market but also for a social eco-responsibility anchored in flexible curriculum. The Mountain Consortium for Knowledge is a program that can be deemed as a blueprint on how educational innovation can drive qualification and economical innovation in the mountain regions by STEAM. This program includes "Impulso Jovens STEAM: STEAM Skills Mountain Knowledge Campus" and "Impulso Adultos: Mountain Alliance for Knowledge and Co-Creation". Each program has three main pillars with dedicated actions and offers to prospective and enrolled students from different demographics, backgrounds, and academic levels.

"Impulso Jovens STEAM: STEAM Skills Mountain Knowledge Campus" aims to provide training in STEAM fields and includes as main pillars the offer of innovative STEAM Masters, CTESPs Impulso STEAM, and STEAM Skills 4 All (10% Up To You!). "Impulso Adultos: Mountain Alliance for Knowledge and Co-Creation" is underpinned by Micro-Credentials and Micro-Accreditation, the IPB Business School and Professional Master in Future Technology and Innovation, and Recognition of Informal Learning (Competence Badges). Besides this program as a set of actions, initiatives, and tools to leverage both programs, enabling students to enjoy an engaging, immersive, and rewarding learning experience, and thus its successful accomplishment. These are the Mountain Future Perspectives Living Lab, the Mountain Future Oriented Incubator and Accelerator, the offer of Grants (such as Women STEAM; PALOP STEAM cooperation, STEAM co-funded innovation; CTESP STEAM Vocational Grants among others) and Scholarships, the exposure to Internationalization, Multidisciplinary topics, Applied Research and the close interaction with the Alumni Community. IPB understands that the education in STEAM is a crucial interdisciplinary living lab, a way to transform and open higher education institution in a tool to create ecosystems of creativity, innovation and technical skills, preparing students and society to face a holistic challenge in a tomorrow future.

B08.

Engineering curricula: what challenges?

C Figueiredo, C Ferreira, B Gabriel[1,2]

[1] Departament of Mechanical Engineer of University of Aveiro, Aveiro, Portugal;

[2] Centre for Mechanical Technology and Automation (TEMA), Aveiro, Portugal (claudiafigueiredo@ua.pt)

The future engineer is expected to offer technical ingenuity and adapt to a continuously evolving environment while being able to operate outside the narrow limits of one discipline and be ethically grounded in solving the complex problems of the future (Nagel et al., 2019a; Nagel et al., 2019b). As a field that has direct contact with society, transformation is inevitable as the world population is changing rapidly alongside technological advancements and growing concerns on environmental issues. It is widely acknowledged that although necessary, a strong foundation in science, mathematics and the underpinning technical knowledge commonly associated with engineering is not enough (Mitchell et al., 2021) to solve real-world problems. Various skills are required to solve real-world problems. The requirement for soft, hard, and social skills is growing very fast to meet day-to-day challenges (Gope & Gope, 2022). It is, therefore, important that an engineering curriculum should be designed accordingly to impart these skills and fulfil the needs of society. To address the competencies of the future engineer, undergraduate education must train students not only to solve engineering challenges that transcend disciplinary frontiers, but also to communicate and transfer knowledge, and collaborate across technical and non-technical boundaries. In this communication we offer a multi-view on engineering education according to the perspectives of different stakeholders from different institutions and positions, representing public and scientific organizations directly concerned professional or educational role of engineers that were invited to participate in the present study focusing on the following main topics: curriculum design, students' skills, integrated engineering, transdisciplinary approach, diversity issues in engineering programs, (re)alignment of teaching and learning, suitability of activities to the challenges of future employers. A category was assumed to have a transversal impact on engineering education and it was represented by the social representations about the course and the profession; the perceived engineering professional profile. That was considered a real challenge because in the stakeholders' perspective these social representations have an impact on the entire course choice process, the curriculum and the teaching and learning process, depending on the role one´s taking.

The diversity of perspectives about what will a better curriculum look like, what is the role of the higher education institutions in response to societal challenges, and what could be the response to more diverse recruitment of students to the curses highlights a debate that is still to be structure and scientifically grounded.

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Acknowledgments

This work was supported by FCT grant EXPL/CED-EDG/1009/2021.

B09.

The GIIP's research: investigation, education and fun

R. Leote[1]

[1] Universidade Estadual Paulista Júlio de Mesquita Filho – São Paulo – Brazil; rosangellaleote@gmail.com

The GIIP "Interinstitutional and International Research Group on Art, Science and Technology" was certified at CNPq by UNESP in 2010. It is directed by Rosangella Leote and Fernanda Duarte.

We are developing investigation that are allocated in six research lines.

We aim to focus on works of art with emerging media where can be observed transductions, at any level, between the three areas that entitle the group, taking into account the contributions of these different fields, in an interdisciplinary way, but prospecting transdisciplinary emergence.

This group is linked to the research line "Artistic processes and procedures" of the Post-Graduation Program in Arts, (level 5/CAPES), at the Institute of Arts at UNESP (SP/Brazil); the activities take place at the Laboratory of Art, Science and Technology.

The dynamic of the work brings together and leads to masters, doctoral and post-doctoral degrees. The participation of undergraduate and graduate students takes place, both by invitation among peers and voluntary adherence, as well as through the role of research guidance for undergraduate research project (PIBIC CNPq/UNESP/FAPESP), masters, doctorates (CAPES, FAPESP or without scholarship) and supervision (with or without scholarship, Brazilians, or foreigners) of post-docs and double degrees, in addition to technical and monitoring activities (scholarship BAAE I and II - UNESP).

The "GIIPers" are 49 people (2022), from Brazil and abroad (through exchange agreements and other partnerships).

The group is continually open to the involvement of new researchers, collaborators or listeners, in its weekly meetings, with part of the team presential and another via the internet. One just need know how work having fun to participate. Due to the pandemics, all activities are being carried out just online.

In addition to artistic activities, our intellectual production involves publications, conferences, seminars, lectures, exhibitions, international exchanges agreements, development of assistive interfaces with intellectual property, transference of free technology and others.

One of the important results that we obtained is the "Zonas de Compensação/ Compensation Zones" extension project, also international. It is a project that opens our research topics that crosses the edge of the University and reaches the non-academic society. There are other extension activities developed by GIIP, which we consider to be very well received.

The GIIP's lines of research are Creation in Art and Science; Assistive interfaces for the arts: from diffusion to inclusion; Neuroscience for Art - Art for Neuroscience; Visual and special effects in audiovisual and shows; Poetics of space and time; and Art/Education Methodologies for people with disabilities.

As the group's research processes involve the collaboration of several Brazilian and foreign universities, interdisciplinary, collaborative and individual projects are developed. They are investigative and/or extensive. The group's synergy impacts the production of its individuals, transforming and expanding their research objects and career paths.

B10.

Local X Change

S. Massey, **S. Derry**
Indiana University of Pennsylvania, Indiana, Pennsylvania, USA (tvls@iup.edu)

Indiana University of Pennsylvania (IUP) is a rural, public institution located approximately 60 miles east of Pittsburgh. Our makerspace, STEAMSHOP, was developed by a group of interdisciplinary faculty from art, business and STEM fields. Many larger universities have larger, more robust makerspaces and related curriculum in architecture and engineering and have demonstrated the positive impact these courses have on the education and retention of URM students. We are working to expand this scholarship by developing curriculum and multidisciplinary collaborative strategies that are adapted for implementation at smaller, rural colleges and universities with fewer resources and a greater number of first-generation college students.

Our STEAM curriculum development efforts have led to the creation of *Local X Change*, which are introductory learning modules that embrace maker culture and attract and welcome all college students including those in their earliest semesters of study and those who lack digital and computer literacy. *Local X Change* learning modules seek to demystify the acquisition of new technological skills by situating technical instruction within a multi-layered collaborative project that is rigorously executed yet seemingly absurd in outcome. One example, Common Goods, asks students to design original paper packaging for items that cannot be purchased, such as happiness, empathy or rainbows. Students translate their paper prototypes into precisely scaled drawings that are then digitized in Rhino 3D software and cut using a large format laser cutter. Laser cut multiples of their designs are installed in pop-up stores in vacant storefronts and proceeds are donated to a local cause.

Local X Change exposes learners to research, technology and professional opportunities as a strategy for impro

ving student success and career preparedness. *Local X Change* curriculum combines the content typically found in introductory engineering, art, and science courses with project-based assignments that engage students and provide them with both tangible technical skills and the ability to innovate, problem-solve, and collaborate. The collaboratively produced, professional presentation that concludes each learning module provides valuable soft skills that will ensure student success, such as confidence, civic engagement, empathy and professionalism.

Creating unlikely or absurd scenarios, such as a storefront selling empty packages or a traffic island transformed into a tropical oasis is way to invite students to consider solutions to problems that they have never encountered. Because these situations are absurd, there are no defined right or wrong answers, only innovative solutions. Rooted in Ratto's notion of Critical Making, *Local X Change* projects offer learners experiences with technology situated within activities that stimulate critical thinking and promote a form of making based in personal expression rather than a rational drive to solve a problem or maximize profit. We have found that this gap between expectation and experience disarms the technological divide separating more technological savvy learners from students that simply have not been exposed to technological resources or have previously had negative experiences with technology. Familiar materials, and/or presentation formats are used to make the acquisition of digital skills attainable for learners that may not self-identify as being technologically savvy.

B11.

MARes: academic research fluidity in Hybrid Arts

Dalila Honorato[1]

[1] Interactive Arts Laboratory, Department of Audio & Visual Arts, Ionian university, Corfu, Greece (honorato@ionio.gr)

As an expression of collaborative transdisciplinarity Hybrid Arts represent both a permeable co-existence in laboratory spaces and a coven for speculative thinking. Opposite to the rigid divide of what is an artistic and a scientific research protocol, Hybrid Arts, as a concept, is a challenge to the process of establishing categories, an embodiment of fluidity. The MARes or 'Master of Arts by Research' in Hybrid Arts being developed at the Department of Audio & Visual Arts at the Ionian University in Corfu, Greece emphasizes independent study over taught instruction and it aims to prepare emerging researchers, either for professional work or prior to a PhD in which theoretical inquiry and experimentation with frontier areas of science and emerging technologies underpin art practice.

B12.

Urban vs Rural Art Practices by Cultivamos Cultura

Marta de Menezes[1]

[1] Cultivamos Cultura, São Luís - Odemira, Portugal & Ectopia Experimental Art Laboratory, Lisbon, Portugal (marta@martademenezes.com)

Cultivamos Cultura is as an institution associated with the Hybrid Lab Network dedicated, since its origin, to the promotion of transdisciplinary knowledge through the development of summer courses and non-formal educational workshops, among other activities. With an extremely active character among different networks and platforms, this NGO is the living proof that independent institutions can contribute enormously to the new hybrid system defended by the most recent EU cultural practices. In its own right Cultivamos Cultura is a place for decolonization of urban art practices: through its in-place contribution to increasing rural art practices as well as its role as an agent for the revitalizing friction between the rural cultural space and the nomadic and temporary rural lifestyles.

B13.

Biofiligree - from Design, through Engineering, to Medicine

Olga Noronha
ESAD-Idea

Biofiligree® is a concept developed within the scope of the project "Study of filigree patterns for applications in biomedical jewellery" developed by a multidisciplinary team, with funding from the Foundation for Science and Technology (FCT).

The project consists in designing, developing, and scientifically testing bone fixation plates using the traditional technique of filigree as cultural heritage of northern Portugal.

The multidisciplinary team with professional and research experience in subjects as Art, Design, Biomechanical Engineering, and Medicine (Orthopaedics) are further developing the concept of 'Medically Prescribed Jewellery', initially developed by Olga Noronha in her Ph.D. thesis "Becoming The Body: An Investigation Into The Possibilities And Affordances Of Medical Jewellery", by designing and testing biofiligree® osteosynthesis fixation plates.

Aiming for the return of the injured limb's functionality and promoting the patient's prompt rehabilitation, post bone consolidation, the fixation plate can be extracted and transformed into a wearable jewel such as a bracelet, a ring, or a pendant, depending on its original size.

Different patterns of filigree will be experimentally tested, and those that offer adequate rigidity and strength for physiological mechanobiology will be selected to be manufactured as osteosynthesis plates. The results of mechanical tests will answer the main research question: Can filigree bone fixation plates be clinically prescribed?