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ARTICLE

Investigating new areas of art-science practice-based research with the MA Art in Science programme at Liverpool School of Art and Design

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ABSTRACT

Collaborations between artists and scientists are increasingly a feature of the cultural landscape. Traditionally this relationship is seen as art in the service of science whereby artists use their skills to visually communicate complex scientific ideas. However, a hybrid form of collaborative, experimentally-driven practice has emerged over the last 30 years where artists and scientists work together to explore the creative possibilities and speculative futures represented by the intersection of these two 'cultures.' The MA Art in Science programme at Liverpool School of Art and Design facilitates discussions and interactions between subjects that have traditionally been studied in isolation within Higher Education. This paper details and discusses the theoretical foundations that have informed the curriculum design and its pedagogical ethos, describes the collaborative learning experiences at the heart of the programme, and offers an insight on how the programme's approach to transdisciplinary art-science collaborative practice could be utilised across disciplines.

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Introduction

Art and science are often seen as two oppositional disciplines with very separate ideas of what constitutes 'research', both in theoretical and practical terms, and relative to its methods and products. C.P Snow's published lecture *The Two Cultures and the Scientific Revolution* (1959) is frequently cited to support this view.[1] Progressively however, collaborations between artists and scientists are becoming a feature of our cultural landscape. Traditionally this relationship has been perceived as art in the service of science, whereby artists apply their skills to visually interpret or communicate complex scientific ideas, objects or forms, for example in medical, scientific or botanical illustration. Such work is seldom described as 'collaborative'; the artist is rarely considered a 'co-author', and instead serves a technical role, despite making an essential contribution to how scientific concepts are rendered legible and interpretable by both professional and public audiences.

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Alongside these applied-art practices, a hybrid set of research-based or experimentally-driven initiatives have emerged where artists and scientists appear to be mutually interested in the creative and speculative possibilities that the intersection of these 'two cultures' represent. Over the last 30 years, art-science collaborations have grown from a niche interest to a legitimate field of inquiry, producing many exciting projects, interdisciplinary collaborations and lively debates across various academic and cultural institutions (Devcic, 2017; Malina, 2016). Such collaborations, it is argued, aim to encourage transdisciplinary creativity and are driven by a mutual curiosity and recognition that a particular objective may only be achieved through unconventional methods. They may also produce, we suggest, opportunities for critical interrogation of knowledge itself, through social, cultural and disciplinary interactions.

Such a position is informed by methodologies within the creative arts that have gained prominence in recent years, including 'practice-led' and 'practice-based' research (Sullivan, 2010), which is often referred to as 'artistic' or arts-based research.[2] Within these, we may find iterations of methods that are more familiar to sociologists and anthropologists, and research findings that are rooted in practical activities and processes.[3] Research activities might take place in a laboratory or a studio, in the field or at a computer terminal, in a single location or across a global network of technological and digital connectivity. In other words, the site of artistic production or scientific enquiry is now an expanded field extending beyond the traditional studio or wet/dry lab as primary sites of data collection, analysis and reporting.

There is a considerable record of projects that have been produced in this space, but less well documented is the potential for rethinking educational programmes that directly engage this space. Here we describe the MA Art in Science programme (hereafter MAAS) at Liverpool John Moores University; a taught postgraduate programme that attends directly to this 'new' space of research and practice, offering new ways to meet the changing dynamics of the higher education landscape, and in response to better preparing students for the future world of work.

The MAAS programme was established in response to an increasing demand for art-science programmes on offer at Higher Education Institutions (HEIs). Subject-specific employment for graduates from UK HEIs is not a guarantee, especially within Art and Design subjects. HESA (https://www.hesa.ac.uk/news/29-06-2017/sfr245-destinations-of-leavers) reports that only 14% of Art and Design graduates at UK Universities during the 2015/16 academic year were employed in the Arts, compared to 69% subject specific employment for those who studied Science. Further taught postgraduate study is a route often taken by graduates to specialise, retrain or advance their practice or skillset (UCAS, 2017, https://www.ucas.com/ucas/postgraduate/postgraduate-study/why-study-postgraduate).

Art-science study has become more visible as a pathway for further postgraduate study, with seven new art-science postgraduate programmes established at UK Higher Education Institutions (HEIs) since 2007. These are listed below, chronologically in order of their first intake of students:

- *MSc Medical Art*, University of Dundee
- *MSc Forensic Art and Facial Identification*, University of Dundee
- *MSc Medical Visualisation and Human Anatomy*, University Of Glasgow
- *MA Art and Science*, Central Saint Martins, University of the Arts London
- *MA Art in Science*, Liverpool John Moores University
- *MSc Science Communication*, University of Manchester
- *MSc Science Communication and Future Media*, University of Salford

These art-science programmes have two key features: they cultivate specialist, transferable skills directed towards future vocational opportunities; and facilitate cross-disciplinary learning opportunities that are not often available to students as discretely defined 'artists', 'scientists' or 'researchers' (Wong, 2016).

In the UK, art-science taught postgraduate study was pioneered by the MSc Medical and Forensic Art programmes, representing two specialised subject-specific offerings. More recent generalist art-science programmes, including the subject of this paper, were established to broaden the approach to what art-science collaboration might look like. The MAAS programme accepted its first cohort of four students in 2016, with students variously holding undergraduate degrees in Fine Art, Illustration and Computer Science. In the two subsequent years, students enrolled on the programme (on average 8 students per year) have held undergraduate degrees from either an art or science discipline (or both) including Biology, Education, Fine Art, Illustration, Linguistics, Oceanography and Zoology. The majority of these students enrolled onto the programme immediately after completing their undergraduate degree, however, in each year group there have been one or two mature students.

The MAAS programme has been designed to provide a range of learning experiences that stimulate intellectual and professional development within the context of both art and science. The programme aims to produce graduates that are able to apply critical, technical and real-world research skills in their chosen careers. The programme team works to deliver an experimental, responsive curriculum that facilitates discussion and interaction between subjects that have traditionally been studied in isolation within Higher Education. A primary objective of the programme is to better prepare students for careers in transdisciplinary environments and the future world of work.

A core ethos of the programme is approaching art and science as complementary knowledge systems. It actively positions itself away from science communication and towards negotiating an experimental zone at the interface of art and science without prescribing specific methodologies or outcomes, echoing this caution from Kratz and Gowers (2017):

> Despite the relative success of art-science collaborations in creative and academic arenas, it remains a field that is poorly understood by outsiders resulting in the wide-spread perception that the primary purpose of art is science communication. Without consideration, the flows between disciplines can also be rather one-sided with artists relying on the expertise of scientists to develop their work with little creative input and limited benefit to their own scientific research.

Yet a number of terms in the introduction of this paper – collaboration, hybrid, experimental, culture – should give us pause. Do we have a shared understanding of what they mean, the claims they make to knowledge, and how knowledge is produced and shared? The continuing influence of Snow's 'two cultures' model suggests we do

not – yet. Snow's lecture was over half a century ago, yet the standoff between art and science as disciplines has grown deep roots. However, the last several decades have shown how artists have found their way into the fissures and fault-lines between art and science. Part of the contribution of such art-science programmes in HEIs, we suggest, are twofold: on the one hand they force us to confront the haphazard theorisation of these hybrid practices, and on the other hand they challenge us to work through the (often messy) realities of interdisciplinarity. This is not about leaving one's prior experience at the door but about recognising our mutual lack of *particular* ways of knowing through our primary discipline. Science Gallery London director Daniel Glaser (2017) recently observed that 'interdisciplinarity is not so much about sharing knowledge than it is about tolerating ignorance…[We should] periodically engage in an interdisciplinary way, but use disciplines to support this'.

Models of art-science interaction

Visual historian James Elkins (2017) has attempted a survey of various models of art-science interaction – there are eight in his estimation – and these serve as an indispensable guide in the pedagogical approach and continuous evaluation of the MAAS programme. His 'Eight Models' were presented as a lecture at the CUE Art Foundation (Manhattan, USA) in 2017.[4] Bracketing his focus between Snow's lecture and his own, Elkins moves through a useful summary of art-science interactions he has observed. These include artists who use science in their practice, collaborate with scientists, or who deploy principles of art in science; those who undertake museum residencies or accompany expeditions; and scientists working as artists, presenting science as art, explaining science in terms of 'beauty' or claiming that art exemplifies scientific principles.

His eight theoretical models (Elkins, 2017, online) are as follows:

(1) Art and science have two separate grammars
(2) Art and science share aesthetics (beauty, the sublime)
(3) Art and science collaborations are a third 'culture'
(4) Art and science are two cultures; there are many
(5) Art and science have common ground ('Venn Theory')
(6) Art and science can fuse to create a hybrid (or convergence)
(7) Art and science share creativity, inspiration, wonder
(8) Art and science are a 'drunken conversation' of 'strange attractors'

He unpacks each model in some detail, providing historical and theoretical references to key scholarship and examples of practices that he considers representative. Further, he details how these interactions have taken place, each of which gesture towards a recognition of mutual interests but also crucially embody the implicit and explicit tensions that have come to define the seemingly irreconcilable differences that Snow articulated nearly 60 years ago. These are useful foundations for the development of an art-science curriculum.

As convenors of the MAAS programme, we do not regard the differences in artistic and scientific methods as irreconcilable. We prefer to engage their affordances and recognise the specificities of particular methods that in turn produce different types of knowledge. To facilitate this, we have adopted a generalist approach that offers

a foundational grounding in the histories of ideas, beliefs and truths that situates art and science as mutually valid knowledge systems, and identifying concepts common to both art and science, such as risk, experimentation and innovation. Being able to deconstruct truth claims and understand the role of science in society, in a similar way to how we talk about the role of the arts in culture, is a key skill for the kinds of 'critical citizens' (Costandius, 2010; Johnson & Morris, 2010) that the MAAS programme aims to produce. Students should graduate in possession of conceptual and practical transferable skills, equipping them for an increasingly precarious future where the very notion of 'work' is being questioned (Harari, 2017).

Incorporating co-design

It can be hypothesised that scientists work to develop solutions for problems that should be testable or repeatable by others in order to be considered 'true,' where artists work to invent problems that only they can solve, and in so doing, reveal particular truths. In proposing research or disseminating findings, artist collaborations with scientists – usually working with very open briefs – often require the adoption of a co-design approach.

Co-design methods stimulate the generation of ideas with a high degree of originality and can improve knowledge transfer and provide immediate validation of ideas or concepts, by challenging students to adopt ideas and practices outside of their own fields. Students are therefore encouraged to draw on many disciplines to approach research problems, working in teams, or engaging external expertise in organisations outside higher education (Mulgan, 2017). Ultimately, this should result in better cooperation between different people or organisations, and across disciplines, with increased levels of enthusiasm for innovation and change (Chisholm, 2016).

Programme structure

The MAAS programme is delivered over 12 months in full time mode or 24 months in part time mode, and is led by a core team of transdisciplinary practice-based researchers with skills representing medical and forensic art, digital visualisation, critical visual studies and curatorial practice. They have established research profiles and operate internationally at the boundaries of art and science collaboration. Developed in consultation with academic experts across a number of S.T.E.A.M[5] disciplines, the programme employs a studio-based curriculum with collaborative practice and discovery at its core. S.T.E.A.M collaborations allow researchers to utilise the strongest characteristics of each discipline to form something new (Buntaine, 2017) and collaborative research practice sits at the forefront of the programme's design.

Our generalist approach, grounded in a critical approach to visual and information literacies, encourages students to examine the relationship between art and science, with respect to history, theory, philosophy and practice, and appreciate how these ideas translate into contemporary experiences.

Designing a curriculum that enables transdisciplinary creativity, where each student is free to explore a different area of science, whether it is stem cell biology or astrophysics – often beginning from a rudimentary knowledge base – is a challenge, particularly with the additional demands of innovation and positive social impact that have

come to define research excellence. One solution in has been to provide students access to a number of different established scientific research centres within the institution and external to it, in keeping with Liverpool John Moores University's ethos of being a 'civic' university.

Within the institution, students automatically become linked to Liverpool School of Art and Design's ART LABS (Artistic Research and Technologies Labs) research centre. ART LABS is a world leading centre for artistic, technological and transdisciplinary research and hosts inquisitive and creative researchers from around the world (https://www.ljmu.ac.uk/research/centres-and-institutes/art-labs). Its aim is to develop useful knowledge through innovative creative practices that connects and defines the future of disciplines. Other partners include the Astrophysics Research Institute, the Public Health Institute, and the Liverpool School of Tropical Medicine; alongside public and cultural institutions including Tate Liverpool, FACT,[6] Bluecoat and National Museums Liverpool. Visiting lecturers and artists working across art-science disciplines expose students to critically engaged making and design practices, and by interacting and learning from with globally renowned practitioners and researchers at our partner institutions, students receive a rich and diverse introduction to a range of international, cutting-edge practices.

To foster a collaborative research culture, students from the seven taught postgraduate programmes at Liverpool School of Art and Design (*MA Art in Science, MA Exhibition Studies, MA Fashion Innovation & Realisation, MA Fine Art, MA Graphic Design & Illustration, MA Urban Design, MRes Art & Design*) share a creative studio. This studio space aims to cultivate an interdisciplinary community, providing students with opportunities for guided and self-directed practice across disciplines and in-depth exploration of key concepts (Tinto, 1997).

There is potential for the 'studio' and the 'laboratory' to become the 'transdisciplinary studio'. The transdisciplinary studio is crucial at postgraduate level in order for students to have access to other members of their community (Elwood & Klenowski, 2002), where knowledge and meaning are actively constructed, and the community itself enhances the acquisition of knowledge and understanding (Rovai, 2002). This studio becomes a learning space that stimulates and provokes student interaction with often complex scientific research principles and challenging art-science concepts. Collaborative learning in this space allows students to become members of the knowledge communities whose common knowledge is different from the common knowledge communities they already belong to (Bruffee, 1995). Merging functions of the studio, the lab and the workshop, our transdisciplinary studio becomes a site for potential cohesion but also intentional uncertainty, representing the potential for institutional and soft-skilled occupants to explore transdisciplinary methodologies. (Coles, 2012) and develop novel research outputs in unexpected forms.

The studio represents the central hub for the delivery of four taught modules (*Studio Practice, Research and Practice 1, Research and Practice 2, Collaborative Practice*) and a student-led research module (*Major Project*), introducing students to critical research techniques, digital capabilities and collaborative research practices. These are summarised in Table 1 and expanded upon below, with illustrated examples of learning activities and student projects that embody the aims, outcomes and values of each module and across the programme as a whole.

Table 1. MA Art in Science module summary.

Module title	Studio Practice	Research & Practice 1	Collaborative Practice	Research & Practice 2	Major Project
Duration of study	Semester 1	Semester 1	Semester 2	Semester 2	Summer
Credits	30	30	30	30	60
Module aim	To enable students to *develop, challenge* and *locate* their personal practice within the art-science field	To provide students with a range of theoretical and methodological tools to conduct practice-based research, and research-driven practice	To provide access to key partnerships and projects representing a range institutional and professional contexts and reflecting diverse social, cultural and economic aspects of the city	To build on critical skills acquired in other areas of the programme, extending to matters broadly relating to research ethics & public engagement	Facilitate a self-directed and in-depth study resulting in a body of work appropriate to the student's research interests
Teaching Activities	Lecture, Seminar, Group critiques, Tutorial, Reading groups, Workshops	Lecture, Seminar, Tutorial, Readingg roups	Lecture, Seminar, Group critiques, Exhibition visits, Tutorial	Lecture, Seminar, Tutorial, Reading groups, Field trips	Tutorial, Seminar, Exhibition
Delivered/learning hours	Delivered: 65 Learning: 300	Delivered: 30 Learning: 300	Delivered: 60 Learning: 300	Delivered: 42 Learning: 300	Delivered: 40 Learning: 600
Learning Outcomes	Evidence a coherent body of work that explores the boundaries of Art and Science, acknowledging a defined audience and/or context, and demonstrating application of advanced skills and processes	An articulate, detailed research proposal in written report form reflecting critical awareness of appropriate literature and arguments relative to the field of study	An advanced proposal or project outcome demonstrating an ability to work collaboratively with peers and/or external partners Skills include networking, communication and organisational awareness, as well as project/ prototype production, publication and dissemination	Produce a contextually aware and critically enquiring text related to the student's specific research interests, supported by appropriate visual and other reference material, formally presented	Evidence research, production and critical evaluation of a coherent and significant body of work that explores the boundaries of Art and Science, with public-facing presentation
Assessment outcome	Portfolio (80%), Viva (20%)	Research Proposal (100%)	Portfolio of Collaborative Artefacts (70%), Reflective Blog (30%)	Dissertation (70%), Reflective Blog (30%)	Portfolio and Exhibition (80%), Viva (20%)

Studio Practice

The *Studio Practice* module's structure fosters an inquisitive approach through introductory 'exposures' and 'encounters' with established S.T.E.A.M and cultural partners that replicate and simulate real-world interactions for making, research and collaborative practice. In addition to lectures, field visits and guided workshops, students undertake a self-initiated project that explores one key art-science concept that they select from a given set, including *Interface, Ecology, Convergence, Synthetic, Body, Data* and *Experimental*. In order to achieve this, students are equipped with baseline theoretical foundations observing, interrogating and proposing how world-class research practices fit with current and emerging art-science research collaborations. Practical exploration of art-science themes and concepts are designed to challenge preconceived notions of the disciplines through peer-based learning. Transferable skills are learned, including digital capabilities such as 3D fabrication, coding and scanning electron microscopy.

Eleanor Gates-Stuart (2013) states that 'people tend to judge the benefits of art-science collaborations by tangible outputs that are generally accessible to a wide audience'. She argues that the process by which these artworks were created can be equally significant, even though it might be largely invisible to anyone other than the collaborators. In this module the concept of 'process' acts as a fulcrum around which we concentrate critical attention on the ways in which knowledge production is conceived from both scientific and artistic perspectives. Related concepts are 'method', 'experimental' and 'publication'. This also echoes how we wish students to approach their practice; attending to cross-fertilization of ideas rather than being outcome or product focused. A portfolio submission, written summary and spoken presentation supports this approach by encouraging students to visually and verbally demonstrate and reflect upon their processes and exploratory undertakings.

A workshop by visiting guest artist Rebecca Beinart in 2017 is described below. It is illustrative of the intersection of studio-based learning activities that utilizes the rich resources offered by our external partners, towards a real-world outcome. We then describe two examples of student projects completed as part of this module.

Guest artist workshop: Rebecca Beinart

One study week in 2017 was programmed around artist Rebecca Beinart visiting Liverpool. Beinart was in the early stages of an Arts Council-funded project *Urban Antibodies* (2017), for which she had invited one of the authors (Smith) to act as a 'critical friend' (a hybrid role incorporating dialogue, reflection and peer-review). *Urban Antibodies* explores the relationships between economic botany, medicine-making, colonialism, and ways in which notions of 'care' and 'community' are crafted or neglected in contemporary urban experience.

The students first met Beinart as a 'fellow explorer' and peer as she accompanied the group on their first visit to the World Museum Liverpool to explore the herbarium and other special collections. This opened up discussions on histories of collecting and taxonomies of knowledge. Thereafter, Beinart introduced her project to the group through an illustrated presentation, which also provided general context for her socially-engaged practice that is framed by the idea of imagining the city of Liverpool as an art-science organism with many living connections.

Figure 1. *Urban Antibodies* studio workshop with guest artist Rebecca Beinart: Students preparing homemade tonic water via hot/cold extraction using cinchona bark, citrus and aromatic spices, and taste-testing it 24 hours later.

Focusing on the relationship between how the trade of quinine and the production of anti-malarial medication facilitated the project of colonial imperialism, Beinart led a workshop (Figure 1) on how to produce homemade tonic water. Using a recommended baseline quantity of cinchona bark, students elected whether to use hot- and cold-extraction, and experimented with their own combinations of various citrus fruit zests (limes, lemons, oranges, and ruby grapefruits) and other aromatics to add flavour. Each 'recipe' was noted, and the containers were sealed and stored to steep overnight for the following day's taste-test.

The following day, the group visited the Liverpool School of Tropical Medicine where established researchers discussed insects as vectors of disease, including mosquitoes, and the uses of quinine as an anti-malarial were reinforced. Back in the studio, students unsealed their tonic water jars and compared results with mixed reactions.

Studio practice student project 1: Unshelved

Unshelved was produced by 2018 graduate Alexandra Emmett in collaboration with the Antiquities Curator at Liverpool World Museum, Dr. Ashley Cooke. The project explores how people *interface* with cultural histories. The aim of the project was to 'unshelve' ancient Egyptian artefacts in the museum collections for use in outreach and engagement with schools.

'Unshelving' is a concept that has developed through application of digital technologies to heritage practices. Selected artefacts are 3D scanned and uploaded to an interactive, online augmented reality (AR) environment, accessible via computer or mobile device (internet-enabled smartphone or tablet) in the museum. This also means they can also be viewed online outside of the museum setting, allowing prior learning to take place in the classroom. The AR environment allowed for 3D models to be enriched with additional data, including object biographies and labels indicating features of significance. Users are able to interact with the artefacts comprehensively from multiple viewpoints and can enlarge areas of interest, which arguably enriches the our experience of them: such artefacts are often displayed behind glass, with only one viewpoint

visible to the museum visitor, and touchscreens afford the illusion of haptic engagement with objects we are often forbidden to handle.

The 3D scanning processes also allowed for new modes of viewing the artefacts in a digital 3D environment, which revealed new knowledge in respect of a faience shabti in the museum's collections. By removing the artefact's 'textures' leaving only the shape remaining, the 'spell' inscribed on the object was able to be seen more clearly without the interference of colour. The text could be more clearly interpreted and so contributed to a more comprehensive understanding of the artefact. Figure 2 shows some of the 3D scanning processes and AR/online presentations of artefacts interrogated during the project.

Studio practice student project 2: Seeds Under Threat

Seeds Under Threat is a collaborative project between MAAS student Raji Salan and seed conservationist Robbie Blackhall-Miles, that explores the concept of ecological threat through the narratives of five seeds of near-extinct plants that the researchers selected to exemplify 'the fragility and resilience of nature, and the power of scientific instruments to reveal as-yet-unseen clues about ecological evolution' (Salan, 2017). The project is presented as an online exhibition (Figure 3), sharing how Salan explored the seeds through scanning electron microscopy (SEM), accompanied by audio commentaries from Blackhall-Miles.

Figure 2. *Unshelved* project: 3D scanning and augmented reality/online presentation of Ancient Egyptian artefacts from Liverpool World Museum's collections.

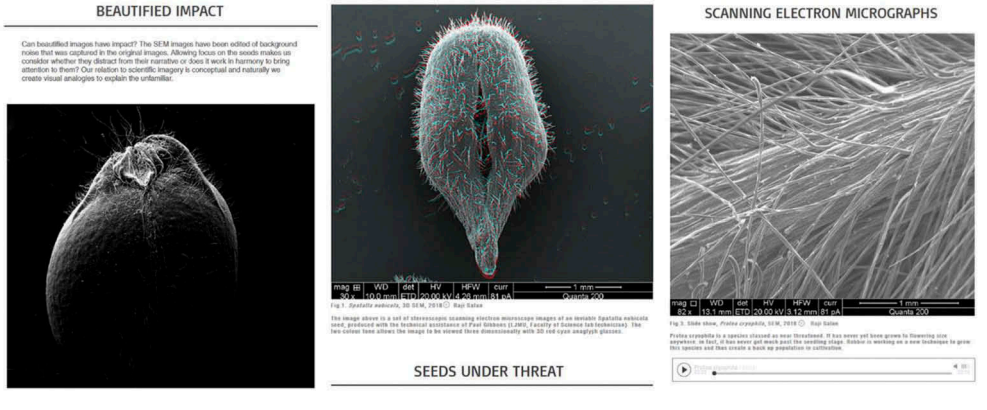

Figure 3. Pages from the *Seeds Under Threat* online exhibition.

Here, the principle of objectivity became central to the project: a critical interrogation of the elimination of doubt through visual observation techniques shared by both the artist and scientist. Engagement with technological apparatus meant seeing closer, deeper, further and in turn, accelerating the production of knowledge about the known universe. Salan utilised visual methods, strategies and scientific devices to foreground the aesthetics of microscopy, validate ambiguity and promote subjective interpretation. In so doing, the SEM images she produced revealed new information about the seed's structures, resulting in re-classification by the seed conservationist and opening pathways to future research.

As an example, *Seeds Under Threat* highlights the benefits of collaborative practice as a research facilitator, demonstrating real potential to promote a deeper engagement with a subject matter, enhance the student experience (Donnelly & Fitzmaurice, 2005) and produce innovative transdisciplinary artefacts.

Research and Practice

Students study two *Research and Practice* modules that place emphasis on engagement with current practice-based and practice-led art-science research, through analysis of the concepts, values and issues that inform study and practice in the field. To enable students to propose and conduct research, consider and deliberate tough ethical challenges, and evaluate their own practice in the context of the real world, these modules provide a range of theoretical tools to help support independent, conceptual and critical evaluation. Students prepare a research proposal and produce an illustrated dissertation that explores one of the modules themes or an area of art-science research linked closely to their career aspirations.

In order to build on the research and critical skills acquired in other areas of the programme the *Research and Practice* modules explore themes that underpin and inform art-science research and practice. This includes being aware of matters relating to the ethics of display; consent, confidentiality and data protection; bio-art, biohacking and transhumanism; working with humans in research, vulnerable people and human material.

> When artists engage with an area of research at a deep level, they have the opportunity to explore and critically interrogate that field in a number of interesting ways, bringing together aesthetic sensibilities, such as beauty or disgust, with intellectual complexity…the majority of people are not able to participate in ethical debates around new technologies – in any kind of considered way – to help decide if a new technology is something we (as a society) want, something we should protest, or indeed something urgently needed. (Dumitriu, 2016)

Learning activity: interdisciplinary ethics roundtable

To facilitate student understanding in how scientists and artists often understand such challenges in different ways, a number of seminars were designed in which the MAAS student cohort were joined by postgraduate and post-doctoral researchers from biological science subjects, a Professor of Stem Cell Biology and members of the Liverpool John Moores University ethics committee. Presented with examples of internationally significant and provocative bio-artworks, including Gina Czarnecki's *Heirloom* (2017) and Maja Smrekar's *K-9_Topology* (2017), and the four principles of bio-ethics as defined by Dana J. Lawrence

(2007); the group debated and discussed their personal thoughts on the artworks but also the potential benefits that such artworks may have on society. These critical debates help to define the setting that the art-science researcher and practitioner faces outside of Higher Education, and included raising awareness of the misuse of cloning technologies and the possible consequences of the controversial DIY science practice, 'bio-hacking.'

To further outline the environment the art-science practitioner works within, students develop and participate in public engagement activities that push the margins of art-science knowledge systems. Bio-artist Anna Dumitriu (2016) suggests that artists also have the ability to reach out to audiences that describe themselves as 'non-scientific'. Artists often are able to 'develop creative approaches in order to open up debates and to share stories and concerns that can be highly accessible while retaining layers of complexity.' Public engagement is a vastly important activity across S.T.E.A.M disciplines, and with funding bodies requiring applicants to embed public engagement activities into their dissemination protocols, artists are being approached more than ever to help develop imaginative solutions that engage the public with scientific research. Kratz and Gowers (2017) highlight that 'there has been an explosion of investment in organisations and public programmes to further encourage interdisciplinary art-science engagement and increase the profile of, and interest in, art and science,' and these opportunities have helped to create a new generation of scientists who are excited to work with artists.

In July 2018 the MAAS programme team and student cohort developed a week-long public engagement workshop at Tate Exchange Liverpool[7] titled *The Perception Machine*. *The Perception Machine* was a working studio-laboratory that became a space for the public to explore and engage with new interpretations of selected artworks on display in the Constellations galleries at Tate Liverpool. Some of Liverpool's leading scientists worked with us to re-interpret and explore overlooked or hidden details of familiar artworks, and their particular 'lenses' of experience revealed unexpected insights. Through a programme of live talks, pre-recorded interviews played in Tate Exchange and a series of interactive activities, the public were invited into a conversational space to listen, ask questions and think about the role of art in science, and science in art.

Participation high profile public engagement events, such as *The Perception Machine*, ensures that students understand how academic and public events are developed, and their importance in increasing the visibility of art-science collaborations in the broader communities of Liverpool and internationally.

Collaborative Practice

In the second taught semester students have the opportunity to work closely with Liverpool John Moores scientific community or with external partners in the UK and internationally as part of their *Collaborative Practice* module. Through key partnerships, students are able to engage with a range of collaborative projects that challenge the notion of the transdisciplinary practice, and that enables them to propose, plan, organise, publish and promote their work within the context of an external body. Challenge-driven models of education support the development of student's skills and knowledge by presenting them with difficult problems, theories and challenges for which there are no or few established answers (Savery & Duffy, 1995).

The module builds upon the foundations set in the *Studio Practice* module, and is shared by the seven taught postgraduate programmes at Liverpool School of Art and Design, allowing students to collaborate across programmes. Collaboration is essential throughout this module and collaborative partnerships provide a platform for cooperative learning in which the community shares the learning experience. The learning experiences are organized so that the students are dependent on the socially structured exchange of information between learners in groups and are motivated to increase the learning of others (Olsen & Kagan, 1992).

Throughout the *Collaborative Practice* module students are supported in developing specific expertise and knowledge in their chosen discipline (Donnelly & Fitzmaurice, 2005) and in doing so are facilitated to develop the skills necessary for employment and for life as a responsible citizen (Fallows & Steven, 2013). The module aims to explore questions including:

- What do we mean by Collaborative Practice?
- Is any activity an act of collaboration?
- Is it about shared goals and ambitions?
- Is it about shared needs, perhaps?
- When should we collaborate?
- When circumstances require it?
- When it is beneficial to do so?
- Is collaboration desirable?

We see collaboration as an enabler, offering an engagement with subjects that may not otherwise be achievable. Collaborative partnerships with fellow postgraduate students or scientific experts allow students to explore opportunities that are truly transdisciplinary and that provide wider impact and knowledge exchange. The focus here is on the act of collaboration, not necessarily polished or fully realised outcomes as a result of the collaboration. A reflective written summary and a portfolio of collaborative artefacts allows for effective assessment of the student's collaborations.

Major Project

The *Major Project* module reflects the summation of the Masters programme of study, where students bring together all the skills that they have acquired on the programme. In this self-directed research module the student is expected to cultivate a research collaboration with a partner from a S.T.E.A.M discipline or cultural institution, and develop a significant body of work, supported by critical reflection and evaluation that is based in scholarly research and current topics of interest. The module is assessed through submission of a portfolio and accompanying critically reflective summary, and a public-facing exhibition.

Previous modules serve as a foundation on which students are expected to build towards becoming expert in their own area of interest. The primary aim of the MAAS programme is to explore the boundaries of art and science, and in doing so, produce new knowledge. 'Working at the boundaries' does not mean making art or design about science topics but is about art and science carrying equal weight. The artist should not serve the scientist's interests and sacrifice their own creative ideas, and vice versa.

So how do we 'work at the boundaries' of disciplines? Developing a shared vocabulary could be a solution and it is during the *Major Project* module that this process is encouraged. It can be argued that art and science share a visual language and rely on similar creative processes (Bailey, 2017), and while this is true of any truly collaborative practice involving specialists from disciplines other than your own, we expect students to work with scientists and learn to 'speak each other's language.' This allows them to protect their artistic voice and be able to critically interpret their collaborator's point of view. Echoed by Wilson, Hawkins, and Sim (2012) such work requires appropriately diverse conceptual, technical and visual vocabularies, and science and art are 'much closer than their institutionalised educational forms might suggest. They both share a similar creative impulse, curiosity and imagination.'

This process can reinvigorate the importance of open-ended exploration and questioning by someone who spent more time simply looking at the subject of scientific inquiry than the scientists themselves (Stevens & O'Connor, 2017). One such example is *Face and Mask: A Metamorphosis of Pain* by 2018 graduate Anthony Pettigrew, working in collaboration with Stephen Fairclough, a Professor of Psychophysiology at Liverpool John Moores University.

Student major project: Face and Mask: A Metamorphosis of Pain

Being a sufferer of the neurological condition 'cluster headaches', Pettigrew aimed to survey and analyse the psychology behind our understanding of the face, masks, pain and how they are intrinsically linked. His project statement notes that 'that people have and show different masks dependent on which social context they are in at any given time. Chronic pain and its links to emotion and empathy change these masks.' Pettigrew (2017) This research journey used 3D face scanning, modelling and prototyping (3D printing) to produce notional masks that represent the artist's personal perception of the pain cycle he experiences during a cluster headache attack (Figure 4). Pettigrew envisioned these forms as proof-of-concept objects that could be individually personalised, printed and used to explain and visualise pain to medical practitioners, which may not be immediately visible

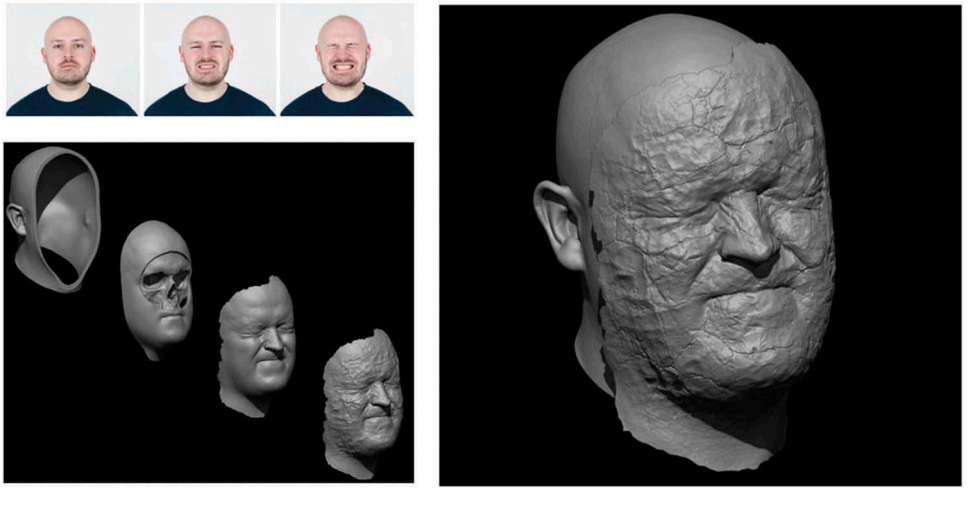

Figure 4. Experimental artefacts from *Face and Mask: A Metamorphosis of Pain.*

or recognisable as outward presentations of pain – a process that could be offered universally to sufferers of cluster headaches.

Because artists are seen to have operational freedom and an ability to critically analyse the world around them, they are seen to be essential in being part of the research process not just in terms of visualizing information but how we understand science and how it impacts on our daily lives (Williams, 2017). Novel art-science research outputs often only become apparent through first-hand experience of interactions, ideas and innovations that would not have happened if scientists and artists had been left to their own devices (Gates-Stuart, 2013) and the *Major Project* module acts as an experimental platform to test ideas and concepts, and often investigate scientific truths.

Summary

> I look at subjects through multiple different lenses. [L]ooking at something only through the scientific lens is too limiting. There are times when the poets get there first. And it's when you multiply perspectives – and for me in this case that means natural history [...] social history, neuroscience, case studies, my own experience [...] I find by multiplying those different lenses is where you really get a full picture. (Pollan, 2018)

Academic and journalist Michael Pollan made these remarks during a public lecture at London's Royal Institute in June 2018 (Pollan, 2018, online). His description of his approach to science communication echoes precisely the ethos the MAAS programme hopes to inculcate in the students we work with.

Art as part of S.T.E.A.M should be disruptive and un-disciplinary to advance existing knowledge systems (Coles, 2012), whereby examining differences between art and science helps to observe their common ground (Decamous, 2016). S.T.E.A.M collaborations should not be seen as opportunistic, political and economic tools but instead, they should push the limits of art, science and societal expectations (Coles, 2012). The addition of Art to S.T.E.M is not to facilitate spurious collaborations but to become a vehicle for human interaction, critique, expression and radical innovation (Stubbs, M. Director FACT Liverpool, personal communication, 10 October 2017), and the potential exists to revisit fundamental forms of inquiry that leave preconceptions behind to form new bodies of knowledge (Coles, 2012).

Artistic Director of Ars Electronica, Gerfried Stocker states that 'artists are no longer concerned with creating artwork that reflects or interprets reality; rather, they want to be active agents in creating it' (Williams, 2017). The programme convenors aim to guide students through core content that provides a foundation upon which they are expected to build upon towards becoming an expert in their own area of interest. Learning experiences on the programme have been developed to combine experiential elements with the establishment of a deep and inquisitive relationship with art-science critical theories and practices, the contexts within which they are deployed and the research against which they are evaluated. Many graduates may go onto work freelance, however there are also a large variety of career opportunities in a range of related sectors. Recent graduates have gone on to work as an artists in residence for University of Liverpool's School of Engineering exploring antimicrobial biomaterials and public engagement, and for bio-artist Gina Czarnecki as part of her studio production team.

It can be argued that in some cases the transdisciplinary outputs from art and science collaborations are artefacts that may have a real-world benefit to society. Nobel laureates in STEM subjects are seventeen times more likely than the average scientist to be an artist, twelve times more likely to be a poet, and four times more likely to be a musician (Root-Bernstein et al., 2008), but as artists and scientists how do we navigate this complicated and often confusing art-science terrain? The authors propose that the outlined MAAS programme methodology could be a pedagogical approach that could be translated across S.T.E.A.M disciplines.

Notes

1. Snow (1959). *The Two Cultures and the Scientific Revolution*, Rede lecture, Cambridge, UK, 'The Two Cultures and the Scientific Revolution' stands as a benchmark for the relationship between art and science in the mid-twentieth century Western world. As Snow saw it, these two critical social actors were playing out a rather unhappy and fractious affair in which neither could communicate on equal terms as each remained largely ignorant of the other's foundational tenets.
2. The distinction between practice-based and practice-led research is generally accepted to be defined thus: if a creative artefact is the basis of the contribution to knowledge, the research is practice-based. If the research produces creative artefacts, but leads primarily to new understandings *about* practice, it is practice-led.
3. Critical visual methods (Emmison, Smith, & Mayall, 2012; Rose, 2016) foreground the application of research tools central to visual arts theory and practice to academic disciplines that have not conventionally considered visual images as research objects (history, anthropology, sociology, law etc.)
4. The lecture was recorded and first published to YouTube by Taney Roniger on 7/11/2017.
5. STEM curricula are based on the idea of educating students in four specific disciplines – science, technology, engineering and mathematics – in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real- world applications (Hom, 2014). STEAM represents the addition of the arts. STEAM education focuses on guiding students in adopting a disciplinary fusion of learning and interdisciplinary thinking (Chen & Xiaoting, 2016).
6. Foundation for Art and Creative Technology.
7. Tate Exchange is an 'open experiment; a space for an ongoing programme of events developed by artists, practitioners. It is a place where everyone is invited to collaborate, test ideas and discover new perspectives on life, through art.' (https://www.tate.org.uk/visit/tate-liverpool/tate-exchange-liverpool).

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