

A New STEAM Age

Challenging the STEM Agenda in Research

Edited by Suzie Leighton and Peter Mitchell

The
**Culture
Capital**
exchange

Inspiring Collaboration

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FOREWORD

In November 2015, at St George's House in Windsor Castle, The Culture Capital Exchange (TCCE) drew together a group of experts from a wide range of backgrounds and disciplines to debate the issues raised by the UK government's STEM research agenda – a policy of promoting education and research in the disciplines of science, technology, engineering and maths over and above those of the arts and humanities.

We called it the STEM/STEAM debate, based on the hope that the arts and humanities might take their place within the roll-call of subjects to whose promotion policymakers might give special attention – changing the agenda from STEM to STEAM.

In this publication you will find transcriptions of the keynote speeches given on that night, and a series of essays commissioned from some of the scientists, artists, academics, engineers and captains of industry in attendance. As you will read for yourself, most attendees agreed that the key challenges of the 21st Century – challenges such as climate change, mass migration and an aging population – are *human* problems more than narrowly technological challenges, and that formulating solutions to them will require a multi-disciplinary approach. More prosaically, you will hear engineers and industrialists make the case that creativity is an essential component of

commercial success – and, in some ways, the last great British export.

This debate is not a new one: high-profile artists, writers and engineers, think-tanks and advocacy organisations on both sides of the Atlantic have for some time been lobbying for a move towards a STEAM agenda, presenting seemingly irrefutable evidence of the importance of the arts and humanities in education and research. However, with the introduction of the English Baccalaureate (EBacc), and the growing disparity in funding research in STEM subjects versus the arts and humanities, a STEAM agenda seems further away than ever.

Why, therefore, did we feel that an organisation such as TCCE should wade into this somewhat crowded public debate? What could we bring to the table to move the quest for a STEAM agenda forward?

Firstly, as an organisation that has been operating in the very fertile ground between higher education research, the creative and cultural industries, and business for the past ten years, we have a unique network spanning all these sectors and beyond. This meant that we were able to bring together an influential and singularly diverse group of people that few other organisations could get together in the same room. With their wide-ranging specialisms and long experience of arts, academia and everything else, they were there to consider the thorny issue of how, and indeed if, we should pursue a STEAM agenda – and, if so, how might we be able to work together to achieve it?

Secondly, our decade-long experience as brokers and facilitators working at the cutting edge of knowledge exchange has given us a deep practical appreciation for the way in which change almost always happens in small steps, in a consensual, slow, bottom-up manner, through small advances, partnerships and alliances between like-minded people and institutions. This approach can often be more effective than the top-down approaches of lobbying, rousing speeches, and letters to the editor. On that rainy November night, we received some very practical insights on how TCCE can work with our network to sow the seeds of a 'Velvet Revolution' towards a STEAM agenda.

Suzie Leighton and Evelyn Wilson
Directors, The Culture Capital Exchange

PROFESSOR GAVIN HENDERSON

Good evening. I was rather struck by the suggestion, in my welcome here, that I had been somewhat responsible for the evening being organised in the first place. I did indeed contact The Culture Capital Exchange (TCCE) in the run up to the recent Research Excellence Framework: we who work in the arts sector and the humanities were very nervous that the agenda was going to be pushed very firmly towards the STEM subjects and I felt that it was the job of many organisations of this kind to make the case on our behalf. If it wasn't, people could easily have said, "Well, there doesn't seem to be any concern rattling around". In the end I think we did quite well. There was another issue running over from a number of years previously, when the Arts Council and the Royal Society of Arts put together an annual series of conferences called State of the Arts. I was very concerned in the first two of those that when they were looking at all the issues surrounding the development and incubation of new work, higher education was not actually mentioned, and nor indeed was the Arts and Humanities Research Council. We petitioned quite heavily with the chairs and chief executives of the Arts Council, and those of the Higher Education Funding Council for England (HEFCE), to try and bring about a change there. It felt like a stark position to be in: here was the Arts Council stating the need to support innovation and research in the arts, but actually ignoring higher education. That has been rectified quite dramatically now; so, in a sense, having discussions of this kind does have some impact in itself.

I'd also like to think about the concept of culture – a word which sits in the very name of TCCE. Some twenty years ago, it was almost a dirty word: one simply didn't talk about culture in Britain at that time. That has changed quite dramatically; but I remember once getting a Continental Airlines flight back from New York, and there was a pamphlet in there about all the great things Americans could do once they hit Europe. It was full of recommendations for European cultural landmarks – when in Milan, it said, visit the Scala, when in Paris visit the Centre Pompidou, and so on. But when in London, all it said was "don't miss the Indian restaurants". Which may well be a fundamental part of our culture, but this said something to me about the way in which we project ourselves. Perhaps we don't like to think of ourselves as a cultural nation.

We've also, I think, been very sniffy about our folk traditions and root culture. This isn't true in the case of the Welsh and the Scots:

"I spent quite a lot of my life working in the field of music, and I feel you could look back and say that funding took us off in a direction which has not been entirely helpful. With the onset of broadcasting and recording, the accountants came in, and they measured things by what already existed, and so an industry developed around a historically received canon."

they happily develop their folk arts, but we don't. When you look at countries like Hungary and Finland, there's a tremendous pride in traditional folk arts. And ours, I believe, got somewhat sidelined with the founding of public funding for the arts, which came out of the Committee for Encouragement of Music and the Arts (CEMA) during the Second World War. I spent quite a lot of my life working in the field of music, and I feel you could look back and say that funding took us off in a direction which has not been entirely helpful. With the onset of broadcasting and recording, the accountants came in, and they measured things by what already existed, and so an industry developed around a historically received canon. And of course, alongside this, there was a need to support contemporary work. As a consequence, that contemporary work which had hitherto been somewhat subversive, and was very much a kind of undercurrent, became in a sense a new establishment, because it was what got funded. So one can look back over seventy years and see what happened in terms of diverging paths, in terms of both our popular culture on the one side, and support for the very new and experimental on the other, which became the primary target of funding.

Of course, we had to try and correct some of this; some people, we knew, felt alienated from the way that the arts were being supported. So we funded all the repertory companies – almost all of them gone now – and theatre and education groups, and a lot of people got their entry to theatre through them. And then there was the community arts movement, which gave us a great opportunity to engage with wider communities in artistic practice. And that too was a great movement, and a very big department at the Arts Council at the time, and that too has now all gone.

I think that if you look back over the past few decades, you can identify a distinct cultural progression in how we fund and administer the arts in this country. The Thatcherite Eighties were, if you like, the inauguration of an accountancy culture. The accountants moved in, the balance sheets were scrutinised, organisations were told to earn more money by

merchandising, and the question that kept being raised was: how much income can you generate? Everything was subordinated to the bottom line. Then in the Nineties the Lottery arrived, and I think we can call that the decade of consultancy culture. Huge amounts of money were suddenly available for people to fund huge projects, to put up buildings. I was part of the Arts Council at that time, and it was quite intoxicating. But a whole raft of consultants developed out of this environment, and John Major's government started talking about 'the vision thing': "Where can we find the vision thing?" And people would sort of say, "Well, we've got all these consultants"; and these consultants were certainly talking to the people who were the real visionaries, but they, the consultants, were the ones holding the reins. And then, I think, through the Noughties, the money disappeared, and consultancy culture was replaced with accountability culture. In this culture, whatever money was being spent, you had to be held fully accountable for it; a whole form of civil service and bureaucracy grew up around the notion of accountability.

And so I'd like to put a question to you that you might want to ponder. We are in the middle of the next decade. How should we look back on how we got here, and what is developing now? I would love to think that we are developing a real respect for artists and creators and the sciences, and a belief that these things can all flourish together, but in a funny sort of way we are not trusted to do that, and building that sort of trust in what we represent is, I think, one of our biggest challenges to understanding. I think one of the issues I'd like to put forward for consideration is that we tend to be about individuals, not about big corporations. So the success that the engineering world in particular has had, in terms of lobbying for the STEM subjects, not just in research at university level but right through the school system, has been impressive. And that's down to the fact that there were some very big industrial and commercial players involved. All the statistics we can find about the importance of our creative industries and the arts world and culture world in terms of the economy are very impressive, but we don't have any big lobbying organisations that hammer this home. Such organisations as exist – the BBC, for example, or the Arts Council – are busy fighting their own corner and trying to safeguard their own resources. So finding advocacy for what we do is a real challenge. I suppose I like the notion – which is also a kind of challenge – that art is like a mineral that forms under pressure, and that we are part of a pressure group, a group that can exert pressure.

We still have a long way to go in persuading the government to change STEM to STEAM; in America, for instance, they're already about two years ahead of us on this. So we have to keep fighting, and we have to

make sure that the research we undertake is respected. To some extent I think it's very difficult for the creative industries, and especially for small companies, to recognise the value of research. It trickles down to them almost by accident. People who work in the arts sector give their time very freely: they're dedicated people and they will get on with their work come what may. Whereas in the pharmaceutical industries, for example, you need huge organisations and laboratories to be able to undertake research work.

So I think there are a number of issues that we have to confront; but while the whole notion of this evening started around the notion of research and indeed the build up to the next REF, I think the argument also needs to start well in advance of that, with the worrying issues within school-age education, with the onset of the EBacc and so forth. There are some very, very serious issues that we have to confront in terms of supply through to higher education. But I do welcome the fact that the Arts Council is now seriously engaged in a dialogue with higher education, and I believe that the Arts and Humanities Research Council, so long as it lasts, is also becoming more widely recognised for what it stands for. The Green Paper is coming out very soon,¹ and we expect it to contain something on the likely future of the Research Councils, probably involving some kind of merger. The future of HEFCE is very much under question. Some considerable change is about to take place – and if we don't speak up, nobody else will.

¹*Fulfilling Our Potential: teaching excellence, social mobility and student choice*. Green Paper presented to Parliament November 6, 2015, by the Department for Business, Innovation and Skills. (HMSO, 2015).

Professor Gavin Henderson
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PROFESSOR JONATHAN GRANT

I'd like to begin by declaring three interests. The first is that I'm a republican (in the non-US sense), so standing here in Windsor Castle makes me feel a bit uncomfortable. The second thing, which will probably make *you* uncomfortable, is that I'm a philistine. I really do not know my Picasso from my Pissarro, my Monet from my Manet. I have friends who explain what those are, and the difference between them, but I'm not really personally engaged in the arts. Thirdly – and probably most important from your perspective – is that I'm a taxpayer. While I may be proud to be a republican, and not at all proud to be a philistine, I am very proud to be a taxpayer.

As a taxpayer and as a philistine, there is a contract between you and me. We often refer to this as a social contract, but I actually don't like that term. It suggests it's somehow abstract. But this is a real, solid contract: I'm giving you money and in exchange you will do something specific. It's mediated through a number of different agencies, so I may not actually see the benefits, but my contribution to society is to pay those taxes so that other people can benefit. In healthcare – and I'll come back to health because it's my area – my taxes go to the NHS, and while I may be well, my dad may not be. I'm happy to pay so that he can get better. That's an acceptable contract – so why shouldn't that contractual relationship be the same in the arts?

What I'm most interested in as a taxpayer is an account: I want you to give me an account of what you have done with my tax money. 'Accountancy culture' may be something we dislike, but it's worth picking apart these terms: *account*, *accountability*, *accounts*, and *accountancy*. What do I mean by an account? I mean a narrative, a story about what you have done. I entirely accept that some things will work and some things will fail, but I think you have a responsibility to give me that account, to give me that narrative.

That's what the REF, the Research Excellence Framework, is effectively trying to do. The government in the UK long realised that in a world of globalisation and manufacturing decline, the only game in town is the knowledge based economy, or the creative economy. Naturally, the government wants to invest, and that should be good news for everybody in this room. This policy shift started towards the end of John Major's government (the first Science White Paper was in 1993) and under the Blair and Brown governments it was carried forward too. The Coalition government and the Tories have

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also broadly carried it on. Research continues to be the flavour of the month, but if you speak to people in the Treasury, and the politicians who are in charge of the Treasury's money, there was a sense before the REF that they were fed up with pumping all this money into the university system, and hearing nothing back. Nobody was giving them an account, and as a taxpayer, I think they were right to ask for one. The REF's innovation was not just to demand an account, but to very explicitly tie funding to the quality of the account they received.

My research interests are in research policy in the biomedical health area, and particularly the problem of how to measure research. I had spent twenty years trying to measure research and suddenly it was going to be instrumentalised on a large scale. I was one of a few world experts on measuring biomedical and health research. When the REF started I spent a lot of time running workshops for sceptical academics, explaining what impact is and why it's probably important that they engage with it, and trying to reassure them it's not as scary as they thought it was. I would sit in meetings with historians and classicists and people like yourself, who would tell me they had no impact. Five years later I was the principal investigator on a project which analysed seven thousand impact case studies using text mining technologies for the Higher Education Funding Council for England (HEFCE)¹. What I learnt from doing that is that every discipline has an impact. If you read those case studies you realise that this is undeniably the case. But as a community, we've never given that account. Whenever I speak, I urge people to go to that publicly available database on the HEFCE website and the next time you travel just randomly download five of those case studies and read them. Every single narrative, every single story, every single account demonstrates to me why I as a taxpayer should fund research – whether it's in the arts, the humanities, history, classics, or biomedicine.

There's a view in this community, and in others, that biomedicine and health research has it easy when it comes to demonstrating impact

and giving the kind of account I'm encouraging arts and humanities to give. But I'm not sure that's the case. If you look at how laboratory-based research translates into improving patients' outcomes, and improving overall health and well-being, the percentage of research that translates from the lab into a new drug or a new intervention is tiny. We don't actually know the precise figure, but one published estimate puts it at one in twenty-five thousand. Another says one in a hundred, and it's probably not much higher than that. The other challenge about biomedical and health research is the timescale: it takes twenty years for research to move from the lab – or bench – to the clinical – or bedside. So why, as a taxpayer, am I happy to invest in something which at best has only a one in a hundred chance of success over twenty years? That seems to make no sense, but we don't question it. So this preconception that biomedical and health research is an easy sell is, I think, wrong.

The important point here is about how that community managed to make that sell, and what we can learn from it. I would draw out two lessons, one of which I'm sure of and the other rather less so. The first is that the biomedical and health community got wise in understanding the need to fulfil their contract, and started talking in the language of impact quite early on (before lots of other people). They became very sophisticated in doing, and presenting, economic analyses that quantify impact. I can stand here now and tell you that for every pound that the government and medical research charities invest in research, there will be a reoccurring forty pence internal rate of return thereafter. We can argue about the methods, but the fact is that forty pence in the pound is in the policy mantra of Whitehall and you hear it on the *Today* programme. That ability to talk in the language of the Treasury, of the paymasters of your research – the language of money – is essential. You may not like it, and lots of clinicians don't like it either, especially when they're essentially attaching a monetary value to human life, but the fact that I can put a value on somebody's life allows me to do the economics necessary to have a good chance of saving it.

The second lesson, which I think is more debatable, is the necessity of speaking with one voice. The biomedical and health funding community was in a state of open warfare about ten to fifteen years ago. But then they came together and began to speak with one voice, at least when presenting cases to the government on spending reviews. The Academy of Medical Sciences and others became a cohesive external advocacy mouthpiece. I'm slightly out of my comfort zone in the arts and humanities sector, but my sense is that there is a greater

diversity of viewpoints than in biomedical and health, so I wonder if it's possible for the arts and humanities to speak with one voice.

I'd like to leave you with three tentative closing thoughts. First, as a sector, arts and humanities has to focus on giving an account, telling a story, and explaining why it matters. As a taxpayer I want to fund you, and I'm supportive, but you have a duty to give me an account – you need to play the game. Second, you may not like the language of economics, you may not like the language of spending reviews and you may not like the boffins in the Treasury, but you need to speak their language, respect them, and engage with them. Finally, think about advocacy and how you can articulate your needs and aims with one unified voice.

¹King's College London and Digital Science, *The Nature, Scale and Beneficiaries of Research Impact: an initial analysis of Research Excellence Framework (REF) 2014 impact case studies*. Available online at www.hefce.ac.uk

Professor Jonathan Grant
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PROFESSOR MARK MIODOWNIK

Thank you very much for inviting me. First of all, I just want to start off with a sort of, well, a statement really, which is that I'm an engineer. And the biggest engineering company in the world is Apple. Now, Apple doesn't bill itself as an engineering company, it calls itself a design company, but it employs thousands, even hundreds of thousands of engineers. Why does it do that? And since it does that, why doesn't it proudly say it's an engineering company? Well, it knows that engineering's a bad word, it knows that engineering doesn't sell products – so it doesn't use that word. It's a very smart company.

The government wants more STEM. By the last count, it wants 1.6 million more engineers and scientists out of our schools: crank them out, get them going. And it wants them in the next few years, and it has worked out it's not going to get anywhere near that number. And it still goes on about science and engineering, saying, "We want more scientists and engineers". But science and engineering don't sell. You might have thought the government would've worked this out by now – Apple has. But it hasn't worked out that the pitch it's making is not going to produce what it wants. This seems odd to me.

The arguments around STEM are not very nuanced, and this is fundamentally because engineering and science have forgotten how to articulate something important about where they came from, which is that they're about humans: they're about human creativity, human desires, human needs and health and all that stuff. That's where these subjects came from, and yet they've somehow distanced themselves from those values, and those values have been taken on by designers, and the arts, and the humanities. And so for me there's something here, something interesting, something worth digging at, because it's something that we can all collaborate on. Personally, I want to see engineering become more vibrant and be recognised as a creative human activity, but at the same time I don't want to see engineers being essentially cranked out as cogs in a machine. We're going down a line that suggests that education is just a big instrumentalised system, that you just need to get a certain number of engineers out there and the whole economy will be fine. It's funny, in a way, because the government even talks about STEM in a tone which apologizes for how dull and technical the whole thing is: "Well, kids, this will be dull and technical, but it'll be nicely-paid too, so off you go and do it for the good of the country, and if you can't have a good life you'll at least have a good mortgage". But what does it mean to have a good life? It means

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having a car and a house and a mortgage, but these are not necessarily the things that people actually want. They're nice, but they're not ends in themselves. So the whole argument falls down, and the kids spot it a long way off – and it's the same reason that Apple don't bill themselves as an engineering company, because if they did people wouldn't buy their products.

So first of all, the whole STEM agenda is not going to work. That's clear. Whether STEAM is going to work I don't know, but STEM, as it's promoted now, definitely isn't. So let's think about what the government is really trying to do. If we're charitable, it's not just about trying to get people to do dull, technical jobs (we might leave that possibility open, though). But perhaps it's not trying to do that: perhaps it's actually trying to solve human problems, and the government knows that you do need very technical people to be able to do that.

One of the biggest problems we've got coming up is climate change, which is going to hit us in a big way in the next twenty years, and there's really very little we're going to do to head it off, so we're going to have to find solutions to it. There are going to be sea rises, and that's going to hit a lot of cities. There are going to be massive changes in the weather, and extreme weather events will become more frequent. We're going to have lots and lots of need for emergency action. Water shortages are going to be massive as soon as temperatures rise further, and mass migrations as a consequence seem inevitable. Where are they going to go, those climate refugees? They are going to come here, and they are going to come here by their millions – they *should* come here, and we should be able to look after them, because that's the point of being human, that's the point of being a global community. We need to find solutions to these problems, but how? Cranking out more technical people doesn't seem the obvious answer. Actually those problems are nuanced, and approaching them in a very linear and instrumental way – as in, here's a problem, here's a solution, now we're sorted – isn't necessarily the best tactic.

Think of the current refugee crisis. On the one hand, you've got people who are crossing the sea in dangerous weather, in dangerous craft, and they need boats. And they need food, and water, and shelter, and transport. These are all engineering problems. But actually, if you just throw engineering at it, you'll end up with an efficient conveyor belt of people, and actually what you want is a compassionate response to them as humans. You want to check their health, find a way of integrating them into society, and you also need to recognise that a lot of them want to return and may need your help to do that. These things are going to take all the skills in this room, all the skills of arts and humanities graduates. But they're not being put to use in that way, and I don't think they're even promoted as potential solutions.

These are our real problems, so if this kind of thinking is going to be part of the STEAM agenda then I'm up for it. I think trying to switch the focus away from jobs and the economy and into real human problems – that to me feels like something I can get behind, and I think young people will get behind it too. And I think, further, that if you can get young people behind it, the numbers will sort themselves out. If you want 1.6 million people who are technically able to do stuff, you'll get them – if they're motivated to solve problems that they believe in, and feel to be urgent, and that they want to solve as a part of the human race.

So what's been done to try to move towards this model? In my own field, I've tried to change the science and engineering landscape a little by creating something called the Institute of Making. We try to reflect how making things isn't just about creating solutions you can sell (although that is part of it), and it's not just about creating things that are beautiful, that we can wear or live in or shelter under or eat with. Beyond these things, it's a process by which you learn about the world and other people, you work in teams because actually you won't get anything good done otherwise, and you grow and learn. What I'm saying is that big problems are not going to be solved by individuals, they're going to be solved by teams, and how do you get teams of people from different disciplines to work together? Well, you need to find the right environment in which to do it.

Until we had the Institute of Making up and running, we didn't have any environment in the university where a set of disciplines could come together and work on a project of their own choosing, and build stuff, or investigate potential solutions in a non-disciplinary-specific place. So that's why we built it, as a place where anyone in the university, staff or students, can come in and start a project up. We've had people

trying to work out if they can give a device to people to test their own DNA so that they can do their own genetic analysis – science for the people, I suppose. And we've had people studying how to create an atheist architecture. And these are very diverse things, but regardless of outcome, a university should be a place where you can play around with ideas – even if only, say, one in every two hundred is actually going to be valuable. But what's a hundred per cent valuable is that everyone in those teams will now have experience of working with other people from different disciplines. And the effect for the university, much of the time, isn't the production of ideas and the success rate with which those ideas become instrumentalised, but the change in people and how they work. If a potter or an art historian or a French expert goes out of the door having worked in a team with a mechanical engineer, an electrical engineer or a computer scientist, it's more likely that both of those people can then, separately or together, have a go at the problems that they really should be having a go at: problems like climate change, mass migration, water shortages. And that's value. That's real wealth. We have the resources in our universities to do this; it's just about reallocating them to this type of activity. So let's do it. Thank you.

Professor Mark Miodownik
 Director of the Institute of Making,
 University College London

ROSY GREENLEES

It's very nice to be here, and I want to talk about my take from the point of view of the Crafts Council. We live in interesting times. Team work seems to be something that everyone talks about: partnership, portfolio working and collaboration are the words that everyone uses. And of course collaboration is always seen as one way in which you can accelerate innovation, because by working together, people with different but complimentary expertise can challenge conventional thinking and find new and unexpected ways of working. In the context of the Crafts Council, it's really interesting that craft makers are entering into that same realm and context, and that they're collaborating, like many other creative people. I completely understand that in that respect we're not unusual, we're no different from anybody else, but I'm here to give our perspective on how this has come about and where we might go next.

Craftspeople are collaborating with scientists, with technologists and engineers, and what that collaboration is doing is providing and producing quite scalable innovations, which might enable growth across a whole range of different sectors. And this is happening, too, in biotechnology, engineering, material science, manufacturing, and many other different sectors. From the perspective of the Crafts Council, we're very excited by this, because what we're looking to do is to account for craft's value in the twenty-first century, to articulate what it can bring to society: how it can make a difference and help solve the problems of our current culture.

So what we've been doing is looking, firstly, at examples of where that's happening, and then trying to understand what it is that makers can bring to the table. So we've just completed four research and development projects with medical academics at Guys and St Thomas', and we published a report a couple of years ago which we're now updating; and we're working with the Knowledge Transfer Network and KPMG to publish a research paper early next year on some of the case studies that we're going to produce to demonstrate these projects' impact. So what is it that makers bring to this particular context? We would argue that there are three very distinct contributions that makers can bring to the STEM agenda. The first one is that makers and designers can explore problems and open out new questions through a process of action, reflection and change. Making is in itself a way of understanding the world, which involves working with and around resistance rather than avoiding it or trying to defeat it.

“Making is in itself a way of understanding the world, which involves working with and around resistance rather than avoiding it or trying to defeat it.”

Secondly, there's the centrality of human sensibility. Makers have, I think, an intimate understanding of how people respond to materials and objects. The ability to convey and evoke human responses through materials and form, and create objects that fit the body and function well, is integral to the work of making. The third thing, of course, is material skills, and it is the immersive nature of craft, and of making as a learning process, that gives makers irreplaceable craft skills and knowledge of materials and techniques. They understand the affordances and the tolerances of materials in a very, very specific way.

So what does all this mean in the context of STEM? Well, let's think about – for example – the first throat transplant, which wouldn't have happened without the glass maker Matt Durran to build the glass moulds that grew the cells that created transplant tissue. Or the pioneering prosthetic arm designed by robotics specialist Graham Whiteley, who had previously been a furniture and automata maker. Julian Ellis, the engineer, uses embroidery in his surgical implants, and the textiles specialist Amy Congdon has developed tissue engineer textiles. Craft and making and materials knowledge is absolutely crucial to all of those different innovations. But the knowledge and the skill is largely tacit, and it's often hidden within that creative process, and here is where we have the problem. We have an education system that doesn't value practical learning and thinking, and a research agenda that isn't necessarily acknowledging and accommodating the value and unique needs of practice-led research.

What we have at the moment is a really serious situation in which the number of students taking art and design courses has fallen by twenty-five per cent, largely as a result of changes in curricula and school performance measures. In his first speech under the Coalition government, the Chancellor of the Exchequer talked about the “march of the makers”. Well, that's not what I'm seeing. Jony Ive, an unbelievably brilliant designer and an expert on things like the

tactile nature of communications devices, says that he can't find graduates who understand both the material and the digital. Fifty per cent of dedicated craft courses closed in the five years between 2007 and 2012. I went to visit a college recently and I met the Vice Chancellor there who complained about people doing practice-led research. They said they lacked rigour. Yet it was the Vice Chancellor's thinking that lacked rigour, because it seemed to me that words are actually the wrong tools for articulating the research carried out in a craft discipline where the thinking and learning is through the act of making. So how do we develop a system of research that really does engender tacit and haptic knowledge and skills, and how do we make sure that the supply chain is not turned off, as it looks like it is being at the moment?

The second problem is that we continue to have silo arrangements between the arts and humanities, and science and technology, and are therefore failing to exploit the potential that we need. We need vision and strategic investment. Talking to bodies that support innovation, what I see is a very linear approach to what they're looking for. They want to set a process going, and then watch it create jobs and economic value. Now, that obviously makes complete sense – we all need to make sure that we're creating that sort of economic impact – but that very linear, narrow way of thinking does not help us to bring these different sectors together in a sophisticated way. We need to bring makers and companies together, we need to find ways of exploring common areas where we can see what the advantages of collaboration are, and we need to take those risks and explore how collaboration works. It won't automatically bring immediate economic value and impact. The question of micro-enterprises is a big issue here. We have a sector which is completely dominated by sole practitioners and micro-enterprises, but a government that talks about small-to-medium sized enterprises (SMEs). An SME is defined as employing twenty-five to two hundred people. Everybody in my sector is much smaller than that. How can these micro-enterprises and sole practitioners talk to universities, how can they talk to government agencies about innovation and the contribution that they can make?

We also need to promote cross-curricular learning in schools. Where can you, in a school, learn about history or physics using clay, for example? There are amazingly interesting ways of teaching children, and particularly children that perhaps don't feel comfortable just working with the written word. I think what's really interesting at the moment is that, of course we're now in a digital world, and that's transforming how things are made – but it's also transforming how

we learn to make, since we can learn how to make things by going on the internet. My son is an example of that: he's learnt how to do all sorts of things, not at school but online. And that's beginning to create new communities of practice, and we're seeing therefore a democratisation, not only of innovation but also of the transfer of skill from peer to peer. You can see the exact same process happening in 'maker spaces', too.

But what does this mean for a formal education system, if all of this is happening outside of it? If that sort of innovation is happening within an informal environment, what does that mean for education and the future of how we bring up our children? We're in a really, really exciting time. There's huge potential for makers to drive innovation in science, technology and engineering. But we need to make sure that interdisciplinary ways of working are embedded in our education system. We have to have new collaborative models to ensure that we end up with STEAM and not STEM. Thank you.

Rosy Greenlees
Executive Director,
Crafts Council England

THOUGHT DRAWN FROM THE BODY: FROM THE CAVES TO THE LAB

The desire of most artists, and indeed most specialists of any field, is to be connected to everyday reality, and play a part in it.

All have differently honed perspectives and specialisms, but they share the same root – an investigation into our lives on this earth, and the good and harm that humans create. By creating a hierarchy between disciplines, are we eroding an equal and necessary relationship entwined into our human makeup?

Contemporary definitions of disciplines are often used to corral them into the shapes prescribed to them by our contemporary society and economy. They appear to be different islands, with the sea between suggesting distance, separation, and the isolation of populations alien to each other. What we need is to be of the same ground.

I chose to be involved in the arts, and more specifically in dance and choreography. Initially I learnt through traditional means, but at some point I was drawn to consider the extent to which movement was part of my infant development. Every action – from the first reachings, stretchings of my spine, pressing up to all fours, stumbling up onto two legs – was part of the process by which I learned to be in the world. The everyday material of my life was a marvel. The everyday was a collection of failures and

successes. The everyday allowed me to be a barbarian as well as to develop into a more social beast.

I can't quite remember those raw early learnings. In fact, I can't remember the precise details of a lot of the library of experiences that's archived in my body. The term I now use for this forgotten-but-present material is my 'compost'. All stuff that has given me direction and shape, but that I can no longer recall accurately, at least in words. Instead, these learnings and experiences have become nutrients for me to draw upon. Amongst other things, they provide me with intuition. I know that these nutrients came from many different sources, and when combined they give me some of the heft I need to make fresh decisions, to have the courage to enter into a dialogue with people whose practice I may not know. My learning supports me to think we can give some genuine creative attention, knowledge, fresh language, and provocation to each other across disciplines.

Our species is made up from an assemblage of attributes that no other creature has. It seems a waste not to include what this complexity may offer us. Some of these

attributes are unnamed and valuable for not being pinned down, but they also represent part of our human enquiry. These more fluid activities might be used as bridges between different disciplines. In my own practice, I recognise research within arts and sciences as having common ground.

I think often of those utterly incredible cave paintings made 30,000 or more years ago. These pioneer members of our human species made marks on rock faces with a great sensitivity of perception. Using their hands, tools and pigments, one can see how they invigorate the movement of the animals by incorporating the curvatures and cracks of the rock faces. I have to think that they brought the whole of themselves to these acts of making. It is a mystery to me how they decided to make such exquisite marks for the first time. What frame of mind or spirit made them make these images in the darkness of a cave? They will have valued these paintings enough to protect them and have them within their sight and touch. To make these extensions to themselves must have required a creative attentiveness and a courage that seem miraculous now.

These works have been approached variously by scientists, anthropologists, artists and art historians. Combined, their insights give us a glimpse of our origins. We need this combination of studies to help us to see the length and breadth of our human natures. We must celebrate the connection between these disciplines in our contemporary culture and maintain the vision of those groundbreaking individuals.

From those first works, the arts need no defence.

Siobhan Davies
Artistic Director,
Siobhan Davies Dance

STEM VERSUS STEAM, VALUE VERSUS VALUES: WHY DO THE ARTS ALLOW SO MUCH POLARISATION?

Talk to anyone involved in interdisciplinary work, and it can sometimes seem that the only real constants are complexity, difficulty and frustration. One hears constantly of the lack of a common language, the inability to understand each other's process, the constant time-lining disengagements, the silo-protective negotiations. It seems we all end up so entrenched in our own expertise, within our own specialist sectors, that we become unable to communicate or engage deeply with other experts.

And yet, as someone who has always worked in interdisciplinary contexts, I am not convinced that this is the whole truth. Certainly, it takes more time to work across disciplines: we need to be co-operative, patient and respectful of the specialisations of others; we need to listen carefully, feel each other out and ask lots of questions, and we need to ponder together, think things through fearlessly, and be prepared – singly and together – to push against our limitations.

Yet for me, this is the most fascinating part of interdisciplinary working practice: the constant learning curve as I work with experts from different sectors, the buzzy challenge as my thinking is shifted in

unusual directions, the wonderful visions as I allow myself to look around distant corners, the previously unseen potentials opened out by specialists in sectors beyond my own.

This being the case, I have to admit that I find the STEM / STEAM debate frankly confusing. Art and design are categorically inseparable from most STEM sector outputs to begin with, and they always have been. Aren't bridges and buildings as much aesthetic objects, built to serve communities, as they are functional exercises in engineering? Are we not proud of UK design heroes such as Jony Ive, without whom Apple could never have been so successful? From as early as

the nineteen-fifties, computer scientists created wonderful artistic visualisations: UK pioneers such as artist Ben Laposky, who used an oscilloscope to manipulate electronic waves that appeared on the small fluorescent screen. This led to the 'Oscillons' series of art photographs, now held in the V&A Collection. This cross-disciplinary intersection of computers and graphics has hugely influenced much of our present day aesthetics.

So this discussion is already many decades old. As Gavin Henderson points out, the US are already a good two years ahead of us in pursuing an integrated STEAM agenda. How, then, can we clarify what needs to be done in the UK, where the STEM agenda still holds considerable sway? The Culture Capital Exchange's St George's House dinner brought together a range of visionary experts to discuss just this question, and as the evening progressed three things stood out for me.

Firstly, it seems clear that the UK arts sector lacks awareness, on a broad level, of both recent and long-term histories of interdisciplinary work – the many creation processes and outputs involving STEM subjects and the arts that have been happening for years. In fact, from my many conversations about this, many in the arts believe these blended interdisciplinary processes have only been taking place over the past decade or so. This has led to a huge (and unnecessary) lack of confidence in talking about the place of the arts in present day innovations.

Secondly – as Jonathan Grant argues – the language needed to convince policymakers about the arts in general is still not quite working. Grant advises "speaking the language of the Treasury when speaking to the policy makers", and feels the arts

is still unable to do this for its pure self as one voice, let alone to make the case for its full involvement in today's multi-faceted processes and outputs.

Thirdly, the arts need to accept that the future demands that the art and design input into STEAM is as much about artistic *values* as about economic *value*. Most young artists / creatives have largely taken this on board, making their livings as small businesses working both commercially and in the public sector.

Is this a generational gap in understanding? One solution may be that to convince government to rightfully put the A into STEM, we need advocates for STEAM who have genuinely worked in STEAM environments. Creatives with knowledge of working in interdisciplinary groupings, people with the right language and the right experience. We need to be able to put forward, through them, the qualitative and quantitative proof for the imperative integration of Arts and Design into the STEM agenda. Then the arts can rightfully and confidently take its place in the modern day interdisciplinary mix through placing the creative back at the centre of the "creative" industries.

Ghislaine Boddington
Creative Director,
>body>data>space

SUPERCHARGING THE UK EDUCATION OFFER

With the creative industries, one of the UK's fastest growing sectors, providing one in every twenty jobs, it is critical that we nurture young creative talent. But a strong cultural education isn't just important for our future economic health. It is important, too, because of the benefits it brings to young people in the here and now.

For most young people, an artistic and cultural interaction provides a creative outlet and an understanding of the structural underpinnings of the society they live in. Regardless of their future career, the integration of arts and sciences enriches children and young people's lives.

Technological development has had a tremendous impact on our work and daily lives, and it is not surprising that these changes have resulted in calls for science, technology, engineering and maths to take centre stage in children and young people's education. But that power is super-charged when you add the A for Arts: from STEM to STEAM. A truly broad and progressive education system demands a STEAM-led agenda that incorporates the arts into STEM subjects, and gives young people the solid foundation they need to make informed choices about their future careers. Witness the fact that, in a bid to emulate the UK, countries like China

and Singapore are seeking to improve their students' creativity.

With these thoughts in mind, it was a pleasure for me to spend an evening debating the merits of STEAM with academics, policy makers, grant givers and others. There was surely no-one in the room who did not think that a STEAM agenda is essential. Rather, the differences perhaps revolved around the extent of our optimism. It's true that the arts aren't in the EBacc, and that it's possible for schools to be rated outstanding without having an outstanding cultural offer. But I am perennially inclined towards a 'glass-half-full' attitude – I think our task is to ensure that young people can receive the fullest possible cultural education despite the structural and systemic impediments in their way.

Local leadership has an important role in determining the strength of the cultural

offer to young people. That's why Arts Council England launched its Cultural Education Challenge recently to encourage leaders across the arts, education, local authorities, schools, higher education institutions and others to work together in fifty Cultural Education Partnerships, creating joined-up arts and culture provision on a local basis. We want these partnerships to deliver coherent local arts and cultural education offers both inside and outside of school, maximising local cultural assets, pooling local expertise and developing shared visions and priorities.

The participation and leadership of headteachers in shaping these local partnerships is key. So too is the input of cultural organisations. The partnerships are modelled on previous pilot cultural education partnerships established in Great Yarmouth, Bristol, and Barking and Dagenham, initiated by Arts Council England in partnership with the British Film Institute, Heritage Lottery Fund and English Heritage.

We've invested £10 million in a network of ten Bridge organisations, tasked with galvanising local partnerships. Bridges are working with more than seven thousand schools - and since 2013 they've brought in more than £11.5 million in additional resources.

We are beginning to see new platforms, partnerships and ways of working at a national level. Recent examples include the TES online platform that gives teachers access to arts and cultural teaching resources from organisations such as the Victoria & Albert, the British Film Institute, and the Royal Shakespeare Company.

Ofsted has confirmed that school inspections must take account of

whether schools offer a broad, balanced and relevant curriculum, and we continue to lobby for it to be impossible for a school to be outstanding without an outstanding cultural offer. We have redesigned Artsmark for schools, and we argue that this kitemark has a place in school inspections.

The artistic and cultural offerings available to our young, in and out of school, serve as incubators for a creative sector which includes industries like fashion, film and music, marketing and advertising, and technology. Given the impact of creativity on these industries, to separate the arts from sciences is tantamount to committing future generations to economic illiteracy. Let's do what we can now to avoid going down that path.

Althea Efunshile
Deputy Chief Executive,
Arts Council England

CREATING A HEAD OF STEAM

In an essay written for the *Scientific American's* blog in 2012, Steven Ross Pomeroy notes that the concept of bringing together arts and science is not a new one. In fact, our efforts to create this convergence within the twenty-first century hark back to much earlier times: Leonardo da Vinci brought the two together in Renaissance Italy.

It appears that, even within contemporary times, those at the forefront of innovation have been merging arts and science practice. Pomeroy notes that “Nobel laureates in the sciences are seventeen times likelier than the average scientist to be a painter, twelve times as likely to be a poet, and four times as likely to be a musician”.

Increasingly, companies and educators are becoming aware that encouraging broad-based skills and multi-disciplinary teams is a good thing. This can be evidenced by the growing number of students taking Liberal Arts courses, which according to the American template allows the pursuit of both arts and science units. The science masterclasses run for gifted and talented school children by the Royal Institution deliberately seek to create a breadth of ability and knowledge rather than merely focusing upon advanced skills. “Our solution is not to help teachers by accelerating the students, because that just stores up the

problem for the next year or year after”, says Gail Cardew, the RI’s Professor of Science, Culture and Society, and their Director of Science and Education. “Instead we stretch the students sideways by opening up an array of wonderfully creative and imaginative topics related to the worlds of mathematics, engineering and computer science. So, for instance, ...students could be learning about maths in fashion, architecture or finance.”

The benefits of mixing arts and science are understood by companies such as IBM, who operate a quota system in recruiting graduates so as to ensure that humanities skills will be developed within the corporation. This is a view shared by Google: in 2011, their vice-president for consumer products declared: “We are going through a period of unbelievable growth and will be hiring about six thousand people this year - and probably four to five thousand from the humanities or liberal arts.”

While there may be little disagreement about the advantages of bringing together arts and science in developing thinking, innovation and technological literacy, there may be some contention over how we train individuals to be skilled in both areas. The English school system encourages early specialisation. At the age of fourteen children decide if they will take double or triple science, and from that point onwards there is little back-tracking, with many schools advising that science A-levels cannot be taken with only a double science GCSE. The proposals for the new EBacc scheme to be introduced for those taking GCSEs from 2020 compounds the issue further. The scheme identifies five core areas that must be studied: English, science, maths, history or geography, and a language. Most controversially, it eliminates the need for any creative engagement with music, art and design, drama, media, or dance. Arguably, the EBacc has been designed as a means of recording schools’ performance rather than as a means to encourage the skills we are likely to need to boost the economy in future.

So how do we create a head of STEAM? The Culture Capital Exchange’s STEM to STEAM debate brought together people from arts, scientific and business backgrounds to advance some ideas. But the challenge in creating a ‘head of steam’ is that there must be sufficient build-up of pressure to create a usable force. This pressure needs to come from business and arts supporters alike lobbying the government with curriculum proposals to create cross-disciplinary programmes such as the innovative BAsc in Arts and Science at UCL, or the BA/BSc Digital Media Communications taught by the Departments of Media Arts and Computer Science at Royal Holloway. It also needs

schemes to encourage cross-working within small-to-medium-size enterprises as well as major businesses. Only through these measures might a real head of STEAM be created.

Professor Katie Normington
Vice Principal (Staffing) and
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Royal Holloway University
of London

THE FUTURE IS T-SHAPED

The UK needs innovation, and in particular innovation in technology, as part of its drive to strengthen its knowledge economy. Based on an evening of stimulating debate at St George's House in November, the argument made here is that in order to achieve this, we need not only to educate people in the STEM subjects themselves, but also to equip them with the skills to be able to put their ideas for STEM innovations into practice. This, we argue, is one of the ways in which strengthening the STEAM agenda could be hugely effective.

The UK's Quality Assurance Agency for Higher Education (QAA) has set out some very helpful guidelines for higher education providers on how to deliver enterprise and entrepreneurship education, to give students the skills to put their ideas into practice. Of particular interest here is enterprise education, which QAA defines as giving students the ability to apply creative ideas and innovations to practical situations; combining creativity, idea development and problem-solving with expression, communication and practical action; and fostering an appropriate mind-and skill-set, where important skills include intuitive decision-making, networking and emotional skills.

Many of these skills, we would argue, can be developed through education in the arts, and students who have studied not just STEM, but a range of STEAM subjects, have at their disposal a powerful toolbox for innovation and entrepreneurship.

The need for individuals with a broad range of skills and competencies such as those above is increasingly recognized in a range of different communities. For example, London's Tech City start-ups are increasingly looking for 'T-shaped' people: people who are both specialists and generalists, having deep expertise in one area and serious competency in several others.

At the other end of the spectrum, corporations such as Xerox and Microsoft Research are increasingly using artist-in-residence programmes to broaden the perspectives of their employees. Xerox's interdisciplinary Palo Alto Research Centre has paired new media artists and scientists to stimulate innovation, and Microsoft Research has an open invitation for artists to work alongside technologists, exploring the connections between art, science and engineering.

Back in higher education, for the past five years I've been lucky enough to be course director for an interdisciplinary Masters programme in Innovation, Creativity and Leadership (MICL) at City University London. On the programme, students study creative writing and creativity in the creative industries alongside modules on design thinking, technology, law and psychology, as well as creative-problem solving and leadership, and delivering innovation from a business perspective. My experience is that a significant proportion of students do indeed go on to become entrepreneurs, often STEM entrepreneurs, developing businesses of their own based on product or service innovations in tech and other domains.

Artists and craftspeople, and more latterly design thinkers, have of course been breaking down silos and crossing boundaries for a long time, but valuable lessons from these experiences have not always reached the STEM community - still less those involved in STEM education and research policy agendas. Many of the structures in place in the UK, at both government and institutional levels, tend to mitigate against individual academics crossing disciplinary boundaries, and truly interdisciplinary educational offerings are hard to sustain.

Policy frameworks such as the Research Excellence Framework (REF) mean that it is still very hard to gain credit in the academic world for interdisciplinary research. However, initiatives such as the EU's recently launched StARTS (Science, Technology and the Arts) programme, aimed at demonstrating the impact of arts on research and innovation in information and communications technologies, as well as interest in liberal arts education programmes in both the US and the EU, are hopeful signs for the future.

In conclusion, if we are to achieve effective innovation, whether in technology or elsewhere, the importance of arts education cannot be overlooked. In today's competitive world, there is a strong and increasing need for more interdisciplinary education at all levels, working to a STEAM, rather than simply a STEM agenda.

Dr Sara Jones
Course Director, interdisciplinary
Masters in Innovation, Creativity and
Leadership, Cass Business School,
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ONE CULTURE, NOT TWO

“The scientist does not study nature because it is useful... He studies it because he takes pleasure in it, and he takes pleasure in it because it is beautiful... What I mean is not that beauty which strikes the senses but that intimate beauty which comes from the harmonious order of its parts.” – Henri Poincaré, *Science and Method* (1908)

There has long been a deep association between the world of the arts and that of the natural sciences. The motivation of the scientist is often not that of utility and pragmatism but something much more intangible, something that is deeply human. It involves the idea of creation tempered by aesthetic considerations. The scientist does not just describe nature; that is not enough. Rather, the scientist constructs a new way of seeing nature that brings out its simplicity and symmetry, and that allows us to extend our world view. The price for this is ever-greater abstraction. The result is then to alienate the scientist from common sense. Copernicus took the earth from the centre of the cosmos. This began the process of the removal of humanity from the centre of nature and our role within it. With the success of science in the twentieth century we are now painfully aware that humanity has no privileged viewpoint. Our description of nature is now driven by such abstraction that humanity and ‘common sense’ have little role to play. Thus there is an ever-increasing gulf between the scientist and the public, and between the arts and sciences.

As conceptual abstraction has become the pre-eminent mode of artistic production, this alienation has also begun to manifest in the arts themselves. Faced with increasingly conceptual work, the public is left increasingly unmoved and confused. The processes of production alienate the scientist and artist alike from the work’s final contribution to society and to humanity itself. This is a problem. Quality of production is tied to the connection between the final product and those who make it. Rather than turning humans into automata, working in specialist roles, the best humanity can offer is when there is a connection with society and the people in it. No matter what abstractions we require as scientists or as artists, understanding the role of these works in our story as humans is crucial.

So we return to Poincaré. There is more in the epigraph to this piece than the obvious impassioned declaration that the motivations of the arts and sciences may be more unified than we often imagine. As humans, we are all creative and enquiring beings; we must embrace that

and not be ashamed to justify our work as a contribution to humanity, whatever that work may be. In 1965, Gordon E. Moore predicted that the power of computing technology would continue to grow exponentially, doubling approximately every two years. Now we see that Moore’s law, or something like it, applies not only to most technologies but also to much of human production, including the cultural realm. This constant rapid growth and development makes it more and more difficult for us to be able to place ourselves and our work in society, culture and history. It is not enough to be the expert, the specialist. In an increasingly fractured world, we need people who can bring together and combine divergent kinds of work.

This is a political challenge as much as an intellectual one. The specialist nature of the UK education system creates the division between science and the arts from an early age. To reverse this will require an investment in education. However, the payback is far beyond the usual five-year political horizon. The long term reward for this investment would be to produce a more holistic society populated with happier people, better equipped to deal with its growing diversity. This is a spectacular challenge, but one that we must embrace. It is time to surpass the artifice of labels and, instead of thinking of C. P. Snow’s two cultures, think of a single universal culture with all its diverse manifestations under a single humanistic label, driven by humanity’s constant need to create and to understand the world we live in.

Professor David Berman
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STEM TO STEAM

Spurred by concern over the decline of manufacturing, the shortage of qualified graduates in technology and engineering, and the necessity of investing in research in the pure sciences, the UK government has in recent years invested heavily in STEM, both as a research agenda and an education framework. Even if only by comparison, the arts and humanities have been somewhat sidelined.

Underpinning this shift is the assumption, common to the late capitalist era, that GDP growth and employment rates are the primary measures of a society's success. The huge political advantage to be gained from investment in STEM subjects is that the outcomes can be measured in monetary terms. The benefit can be described by a single number that is easily talked about and readily understood. Meanwhile, I am told that we have experienced the demise of half of all craft courses in the five-year period from 2007 to 2012. This is an extraordinary rate of loss. Much of the effort that goes into making engineering projects work is becoming increasingly farmed out to computers. Soon, everything that can be automated will be, and artificial intelligence will deal with many of the more utilitarian tasks of work and daily life. But it is creativity and ingenuity that most distinguishes human endeavour, and the progress of civilisation that best measures

the development of our society. The creativity, ingenuity and instinctual artistic work inherent in design are skills that are very difficult to automate; in this sense they are future-proof, in that they will never imaginably be superseded. They are also, fortunately, skills in which Britons excel. But these attributes seem not to feature in the STEM agenda; so should STEM incorporate the Arts and become STEAM? Personally, I find this a slightly puzzling question. My first thought is to ask what the STEAM agenda misses out, and indeed to wonder if I've missed some subtlety in its makeup. Doesn't it just include everything? Perhaps STEAM's real value lies in precisely that all-inclusiveness: it describes a diversity of education and research, a full spectrum of activity, which one can see almost as the educational equivalent of biodiversity. Then, of course, we have to contend with the distinction between research and educational agendas.

I tend to care more about education, which seems to me to be about producing people rather than data – although, of course, research is necessary to produce knowledge which can be taught. But 'research' in the traditional sense of the word may not always be the best term for what we need to do. How, for example, do you do 'research' in design? Trying to fathom the design process is one thing, but what we really want are better designers. And designers learn and grow through doing design. What they need are patrons and commissions, to help them develop a strain of research that is explicitly practice-led; opportunities to learn and improve through practice. How does this fit with the agendas of our Research Councils? And how, finally, should we account for the benefits of Arts activities? We often hear that they are best expressed as narrative or stories. I am a great believer in storytelling; it enriches our lives and engages audiences with the subject. But it is hard to quantify and aggregate in simple numerical or monetary terms – hard to turn into the kinds of numbers that make policymakers and taxpayers look favourably on you. Perhaps we can measure the volume of stories or the quality of narrative. And as we accumulate more and more stories, information technology may help guide us to the story we really want to hear, and that funders need to hear, too. But all this is secondary to the main issue. A society's strength should be measured as much in its civilization as in its GDP, and to become more civilised we must invest in the arts.

Tristram Carfrae
Deputy Chairman,
Arup Group

THE UNDISCOVERED COUNTRY (FOR TECHIES)

*“The undiscovered country from whose bourn
No traveller returns, puzzles the will
And makes us rather bear those ills we have
Than fly to others that we know not of?”* (Hamlet, Act III, Scene I)

Many of us are creatures of habit and will be quite content to stay in the tramlines that we wore early in our education or in our careers. Doing otherwise is usually more effort and perhaps more of a challenge to our individual sense of status within our field. I suspect this to be true from both sides of the STEM / STEAM debate, though I can only really comment from the STEM perspective.

It seems to some of us engineers that the vast domains of human imagination and endeavour that are the creative and performing arts are in some way foreign to us – an undiscovered country. Although we might engage with the outputs of these arts for our entertainment and cultural enrichment, the processes, structures and jargon of the arts are as obscure to an outsider as those of any other domain. Are these territories really so different? Can we map the various stages, from research through development to prototyping, manufacturing and utility, from engineering onto equivalent phases in the arts? Should we even try to?

There are clearly parallels, whether it is the sculptural nature of scientific discovery, chipping away at the rock

which is hiding the beauty of a discovery, or the choreography of engineering, bringing all of the parts together at the right time to create a harmonious whole. There are also tools common to both domains: heuristics, such as Occam’s razor, which guide us through the complex territory of problem and solution, or the principle of passing on knowledge and craft through apprenticeship.

We must also consider the economic substructures of our disciplines: how are our efforts monetised, and how is consumable value exchanged for the fruits of physical and intellectual labour? In engineering, an economic shift from patronage to utility – from the funding of powerful donors to a mercantilist economy in which widgets could be sold based on price and quality – generated new funding for future projects, and expanded society’s absorptive capacity for the products of technological change.

Just as important, perhaps, is the development of a taxonomic framework on which the whole discipline agrees. Consensus on what to call things and how

to classify them lays the foundations of both standards and standardisation, without which engineering would be sunk: standards allow us to discern between the acceptable and the non-acceptable; standardization allows engineered products, their consumers, and engineers themselves to work together, and enables interoperability, mechanization and the increasing automation of production and maintenance tasks.

We can see how this progression to automation has happened in the relatively young field of information technology. The roots of IT as we know it can be found in many places, but one of them is the work of Herman Hollerith, who invented the punched card and founded the Tabulating Machine Company in 1896. This technology automated the collation and sorting of data printed on punchcards. Hollerith’s company was one of four companies consolidated together in 1911 as the Computing-Tabulating-Recording Company, which thirteen years later was renamed the International Business Machines Corp – or, more snappily, IBM. For the next couple of decades, information technology was the technology of collation and sorting, until calculation itself started to be automated – the earliest practical automated calculating being that done by Konrad Zuse’s ‘Z2’ electromechanical computer in 1939. In the decades that followed, electromechanical methods of automated calculation were superseded by electronic ones. Now, in the present day, we are beginning to develop the technologies with which to automate pattern recognition and simple reasoning – building blocks of what we think of as cognition itself. In this we are using IT as a co-processor for the brains of people, amplifying their abilities.

We know what bankers and insurance companies do with IT capability.

We know why physicists and genomics researchers want high performance computing. But what about dancers, artists, philosophers or ethnographers? What is the progression for the tools and taxonomies in their domains, and what might result from applying the huge co-processor that is IT to the brains working in these fields?

Given that the focus of many of the non-STEM disciplines is to explore the very things that make us human – more than just meat-based cognitive machines, creatures of habit and simple wants – perhaps it is time some of us travelled a little further out of our comfort zones.

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