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The value of instability: lessons from reviewing how and why creativity and the arts might interact with STEM education

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Abstract
In late industrial economies**,** STEM education in schools has significant political support. In recent years interest has been shown in bringing 'the arts' into some integration with STEM practices; the 'STEAM agenda'. A recent review of the STEAM literature and practices in the UK struggled with the difficulty of developing a coherent and meaningful account of the STEAM literature as a whole. This review noted that the majority of the literature was concerned with pedagogy and only to a limited extent with issues underpinning the purposes of education. In this paper we consider, through the lens of curriculum theory and use of a specific case study, three of these underpinning issues: the place of the arts, the rejection of monodisciplinarity and value of new conceptions of science. Whilst making sense of STEAM literature and practice is difficult, we argue that there is a need of a more nuanced analysis of these issues which challenges an easy political accommodation; pays attention both to educational foundations and educational practice; and promotes the need for critical and ongoing dialogue between STEM practitioners, artist, teachers and educators.

Keywords: Curriculum; STEM; STEAM; Arts; Imagineerium.

1. Introduction

The 'STEM agenda' (Science, Technology, Engineering and Mathematics) has significant political support in late industrial economies. In recent years interest has been shown in bringing 'the arts' into some integration with STEM practices both in schools and in higher education; the 'STEAM agenda'. A recent review of the STEAM literature and practices in the UK[1] (Colucci-Gray, L., Burnard, P., Cooke, C., Davies, R., Gray, D., & Trowsdale, J., 2017) struggled with the difficulty of developing a coherent and meaningful account of the STEAM literature as a whole:

> Whilst STEM has currency as an essentially economic term ... the pedagogical and curricula implications are less obvious. STEAM retains this lack of educational clarity, indeed adds to it, by virtue of: firstly, being itself a portmanteau term; secondly by having varied modalities and associated purposes; and thirdly because the terms 'art' and 'arts' are also used interchangeably and often uncritically... It is also unclear whether STEAM is intended to imply a reconfiguration of disciplinary relationships ... Further, it is unclear whether an arts-infused or arts-integrated approach is implied… The conceptual issues are further complicated by an apparent conflation of STEAM with creative approaches to teaching in the STEM subject areas... (Colucci-Gray et al, 2017, p. 8).

The review recognised that a significant proportion of the literature related to pedagogical techniques to inspire and motivate pupils to engage with STEM subjects. One project, noted in the report, 'STEAM Co.' (steamco.org.uk), an innovative and well respected project which uses arts, creativity and 'edutainment' approaches in primary schools provides an illustration of this tendency. As Morgan et al (2016) have recently reported there is a clear need for work to overcome deficits in younger pupils' scientific and proto-scientific understanding. Further, the literature points to the pedagogical effectiveness of these type of STEAM activities to increase girls' involvement in STEM. However, such approaches tend to see '*the arts*' as a handmaiden to STEM education, retain a broadly monodisciplinary structuring of education, and do not question dominant accounts of science or the purposes of schooling. These points were identified as problematic by Colucci-Gray et al. It is these questions, which link directly with *curricula* rather than *pedagogical* issues, that are the focus of this paper.

Central to our discussion is a particular case study, *'The Imagineerium'*, which we treat 'normatively'. Following Levinson and Fay (2016) we take normative case study to provoke the development of 'educational theory that provides context-sensitive guidance to the education profession' (Levinson & Fay, 2016, p. 3). The case study on which we focus is a small, arts and engineering project located in a post-industrial city in the middle of England. This project emerged from the review as 'atypical' and which provides a fertile site for exploration of the more general points. *The Imagineerium* is not proposed as an ideal type of STEAM educational project, but as one which facilitates discussion of both curriculum and practice. In explicitly drawing engineering and arts together at a foundational level, it seeks to see the arts as having a fundamental role to play in pupils' education. It suggests that the arts are intrinsically valuable, contributing to pupils' understanding of engineering and design and in creating an arts/engineering hybrid, reflected in the terms 'imagineer'[2] and 'imagineering'. Its 'atypicality' emerges as a result of a contingent relationships between community artists, engineers, educationalists and teachers.

We place this narration of *The Imagineerium* in the context of, in §2, theorising about the curriculum and, in §3, a brief account of Colucci-Gray et al's (2017) review of STEAM. In §2, we discuss the role of curriculum theory, and our conception of it. We also set out an account of a curricula structured not in disciplinary terms (as it often is in the U.K.), but by 'knowing that' and 'knowing how'. We also argue that making sense of STEAM education in terms of the curriculum requires a concern with both educational foundations and practical 'schemes of work'. In §3, we set out the difficulties in developing an intelligible

framework within which to report the findings of the review, and the key features of that review which indicate the need for an analysis at the curricula level, namely the issues of: the role of the arts; thinking and working beyond monodisciplinary silos; and engagement with more explicitly axiologically informed conceptions of science.

Finally, we note the significance for our approach of 'making sense' of STEAM literature and practices. Academic papers tend to imply a linear argument as sections progress. In §2 and 3 we frame the argument on STEAM in terms of curriculum and literature before considering our case study. The analysis of *The Imagineerium*, however, requires that those frames provide the resources to make sense of what, *in practice*, is going on. As such the linearity of this paper, whilst necessary, does not reflect the more dialogical relationship between the selection and discussion of ideas in §2 and 3, and the narrative of *The Imagineerium* presented in §4.

2. The task of curriculum theory

We take it that curriculum theory, Janus-like, looks both to those educational foundations that inform what ought to be taught and the how curricula ought to be structured, and also to the needs of curriculum designers and teachers. Hence, curriculum theory requires two anchor points: to be distinct from educational foundations in its practical utility, and to offer theoretical foundations which do more than describe curricula and curricula practices.

We are not here claiming anything particularly new. Pring (1976, 1977) sets out a series of critiques of educational scholarship in the early 1970s. He was critical of work by Paul Hirst on the grounds that it lacked practical utility and Michael Young on the grounds that it was insufficiently theoretically robust (see also Davies, 2016). In different ways, and to different degrees, both Hirst and Young have accepted the validity of these criticisms (see Hirst, 1999; Young, 2016). In fact, Young (2013) has made similar criticisms of curriculum theory.

Young's major criticism of the field is that it has failed to maintain a critical dialogue with theories of knowledge, and specifically, a theory of 'powerful knowledge' as central to the purpose of schooling. Whilst we remain agnostic on the validity of Young's particular answer to the question of the way the curriculum ought to be structured, nevertheless his broader point on the need for clear, reasonable principles that are open to public scrutiny is one which is well made. There is also a second, more discrete, criticism in Young's account. This is the contemporary negative trend which Young notes (2013, pp. 104-5), drawing on work of his (former) allies in 'Knowledge and Control' (Young, 1971). The criticism is that such theorists have maintained a concern with foundations, notably neo-marxist critiques of education, but have not paid sufficient attention to practical relevance.

We think, therefore, that Young's call to knowledge as a structuring principle is helpful for our exploration and articulation of STEAM curricula. However, we develop this account not primarily in the sociology of education, but in work more traditionally identified with philosophy. The resulting account is more general. Whilst allowing a possible reading that foregrounds a concern with developing 'powerful knowledge' as a core purpose of education, it also offering other possible readings. We purposefully, that is, want to leave open the

possibility of other readings which are useful for the practical development of STEAM curricula with different educational purposes.

Ryle's (1949) distinction between 'knowing that' and 'knowing how' has been a matter of interest with longevity in educational thought. Although there have been a number of debates as to whether 'knowing how' is really a form of 'knowing that', and more recently arguments that 'knowing that' *is* a form of 'knowing how' (see Hetherington, 2011); the distinction allows us to reasonably frame discussions of the theoretical structuring of STEAM education. Hirst (1974) and Phenix (1964) both reflect a primary emphasis on 'knowing that', and the later Hirst (1999) and Dewey (1938) have an emphasis on 'knowing how'[3]. It is helpful to make a further distinction between 'form' and 'telos', that is between the 'theoretical structure of the conception of knowledge', and its 'purpose'. The latter is necessarily directly linked to the purpose of education in general. (See Scarlett, 1984, for a discussion of 'form'[4] and 'telos' in relation to Hirst's work.) A particular conception of knowledge may have theoretical rigour, and coherence, but this is not sufficient for its adoption as the basis for a curriculum. Such a basis requires consideration of the purposes of that curriculum and the suitability of the 'form' for that 'purpose'.

So, we mark two distinctions in relation to the underpinning foundations of the curriculum, that between 'knowing that' and 'knowing how', and between 'form' and 'purpose'. We recognise that other possible conceptions of knowledge, or theoretical ideas drawn from other foundational disciplines, can be utilized. The point here is not to resolve fundamental questions in epistemology and ontology, but to establish frames to make sense of the themes already explicitly intimated in relation to the literature on STEAM education.

In the light of this conception of the task, we now briefly review some elements of Colucci-Gray et al's (2017) review, recognising that the constraints of space exclude a number of aspects and the subtlety of the original review.

3. STEAM: in literature and practice

STEAM approaches to education are those concerned with at least one of the STEM disciplines and one arts practice (see Colucci-Gray et al, 2017). In our case study, *The Imagineerium* focuses on one STEM area, engineering, and a range of arts practices. However, it is worth noting that the practice of engineering enables pupils to learn concepts and processes that are often identified in school as part of the science or mathematics classroom. Artistically, *The Imagineerium* draws on physical theatre, as well as art and design.

In this paper we will develop two aspects found in Colucci-Gray et al's report (2017). The first is to distinguish between literature which is concerned with pedagogy and that concerned with foundational, or underpinning issues. The second is to highlight some of these underpinning issues which raise the need for further exploration.

In particular, we want to distinguish between those accounts which see the arts as just a pedagogical device and those for whom the arts are integral to curricula structure (recognising that the latter also implies an impact on pedagogy). We agree with Hirst (1974, p. 2) that although curriculum content and pedagogical methods are closely related we can, and it is often useful to,

distinguish between them. In particular, we note that by far the majority of the literature considered by Colucci-Gray et al (2017) relates to small-scale evaluations of pedagogy rather than curriculum. Additionally, whilst the STEAM literature on creativity showed 'clear evidence of creative approaches to STEM teaching which motivated pupils … these projects tended to be "one off" or short term, and externally staffed' (Colucci-Gray et al, 2017, p. 10).

Colucci-Gray et al note that STEAM is primarily a 'hybrid pedagogical conception' (2017, p. 16) which is reflected in the majority of the literature and practice; a point, we argue, that is at the heart of the challenges as well as possibilities for STEAM. However, there is also some literature concerned with areas of contestation which are foundational, epistemic and ontological. These included the nature of science and its relationship to science education, the role of the arts and creativity in education, the purpose of education, and the limitations of thinking and working in monodisciplinary silos (2017, p. 14ff). The distinction between the pedagogical and the curricula is exemplified in the report in the two-stage literature review. The key themes identified as significant by science, and arts educationalists are discussed in the first phase of the literature review, and tend primarily towards foundational issues often without any clear account of their implications for curriculum. The second phase of the review, a more focussed keyword search of the educational databases directly identifying STEAM literature, tended to be concerned with pedagogy. To summarise the review, the concerns of educationalists involved with STEM education and those involved with arts education (and the use of arts in education) tended to be concerned with what can be known and how we know it, and by implication what ought to be taught. The distinctively STEAM literature and practices reviewed were, largely, concerned with improving STEM pedagogy.

As noted previously, the point here is not to set out a hierarchy of significance. Clearly pedagogical developments which seek to improve pupils' motivation and the inclusion of groups traditionally less well represented in STEM subjects and employment is to be welcomed. Rather, the point is two-fold. The first is that a distinction between pedagogy and knowledge is reflected in the literature, and the second that these epistemic foundational issues are in need of further development. In particular, although the literature raises the importance of critiquing monodisciplinarity, contemporary accounts of science, or the importance of the arts, rarely is there consideration of the practical impact of these on STEAM practice. Neither are these issues clearly related to different (and competing) conceptions of the purpose of education. In the language employed in this paper, there is in the literature concern with 'form', but a less clear explanation of 'purpose'.

The first part of Colucci-Gray et al's (2017) literature review articulates three themes. The first notes the definitional and conceptual difficulties apparent in the literature. The second sets out a range of difficulties with articulating a coherent account of the field that is the lack of a clear taxonomy of related STEAM projects and practices. Whilst there is some clarity about what STEM looks like, the different meanings, and uses, of the arts (or arts or creativity) make it difficult to outline a family relationship. The response is to present the literature and STEAM practices as a series of responses to a range of criticisms: of science and technology generally, its normative relationship to society, and of

STEM education. Two points emerge which are significant for our argument here. Firstly, there is a distinction between two purposes of STEM education: an education as a basis for a future role in a STEM occupation, and an education in STEM literacy suitable for a citizen in a modern society (Colucci-Gray et al, 2017, p. 34). They quote Rudolph in noting that the 'goals for developing citizens - look (and should look) different from a science education for … disciplinary expertise' (Rudolph, 2015, p. 1075).

Secondly, the changing contract between science and society which, in part, reflects a direct sustainability and environmental agenda:

> While these global issues provide a focus for the attention of science and politicians looking for 'solutions', another side of the coin is the fact that the increasing scale and power of science and technology...has actually contributed to many of these problems (Gray & Colucci-Gray, 2014, p. 20).

Here science, as it is presently construed, is as unable to respond to contemporary challenges:

> These *wicked problems* pose significant challenges to … traditional scientific approaches by exposing the inherent difficulties with a simplistic, reductionist view of science and technology (Colucci-Gray et al, 2017, p. 35).

These two issues are foundational, and question what *form* of science knowledge is, politically and socially, deemed to be more valuable. These issues link with a stronger epistemic issue articulated in terms of posthuman or postnormal science. They also link to questions as to the *purpose* of education, and STEM/STEAM education in particular.

The third theme, in the first phase of the literature review, is a series of summaries of the literature in relation to different aspects of epistemologies and ontology. It is worth noting, that Colucci-Gray et al do not attempt to validate the claims made in the literature, but seek to bring some order to what has been claimed in relation to activities identified as STEAM. They deal initially with the rejection of a monodisciplinarity account of STEM/STEAM.

> These critiques have force in two directions. The first is in questioning the legitimacy of our present conceptualisation of the discipline(s) of science. The second is to direct attention to the need to move beyond 'monodisciplinary' approaches to STEM education. Where the first is evident in the literature, it tends to be in support of a humanising of STEM education, through and by the arts (the mechanisms being unclear), which supports a critique of neo-liberalism and concern for sustainability issues. This is often categorised in terms of 'post-human' or 'post-normal' science… The second reflects both pragmatic and epistemic discussions on multi-, inter- and trans-disciplinary working (Colucci-Gray et al, 2017, p. 36).

Posthuman and postnormal accounts of science and technology 'argue for an epistemology in which we move away from humans as being at the apex of knowledge' (Colucci-Gray et al, 2017, p. 36). They identify posthuman:

> ...as refer[encing] the complex socio-material constellations in which certain human, non-human others and the biosphere participate equally but differently in the creation of alternative environments of existence (Papadopoulos, 2010, p. 194).

In this section they identify a series of themes related to knowledge. Knowledge is conceived of as: contextual and situated, linked to the environment,

embodied, and perceptual (Colucci-Gray et al, 2017, p. 39ff). It is worth noting that these categories tended to emerge from work grounded in the arts, and *perhaps* reflect dominant aspects of arts based practice generally and arts based education in particular. This first phase of the literature review, and especially this section on epistemology and ontology, explores the impact of viewing the role of the arts as more than a pedagogical tool to develop STEM knowledge. Rather, knowledge itself is to be questioned and the arts, as a range of different disciplines, offer both a site for such questioning and a central aspect of the emerging conceptions of STEAM. In this paper we focus on these aspects to develop the curricula debate in relation to STEAM education.

4. Case study of a STEAM curriculum model: The Imagineerium

As we noted earlier, curriculum theory needs, Janus-like, to look both to foundational issues in education and the practicalities of educational practice. *The Imagineerium* is a practical educational project hybridising engineering and the arts in order to develop pupils' understanding of ideas within the STEM related disciplines, as well as supporting broader, general educational objectives. It has characteristics which are both typical of other 'STEAM' projects and characteristics which are atypical. It is this element of 'atypicality', along with the insight provided by one of the author's ongoing research and evaluation of this project (see Trowsdale, 2014; 2016), that has shaped our thinking about STEAM curricula and the complexities of the literature reviewed by Colucci-Gray et al (2017).

Telling the story of *The Imagineerium*, as with any story, requires a structuring and editing of what might be said. Here, we are concerned with the broad sweep of the project as a series of stages of growth of a STEAM curriculum, rather than the details of pupils' pedagogical interactions. The intention is to consider the key characteristics and rationale for *The Imagineerium* becoming the kind of STEAM project it has, and the ways in which foundational issues appear to have impacted, perhaps tacitly, on its development. At present *The Imagineerium* is beginning a stage of enabling others to join and 'emulate' its practice, that is looking at the viability of a roll out of the project in other places and involving a wider group of individuals. This stage of 'emulation', the project's third, involves an increasingly self-critical reflection and codification of *The Imagineerium*'s 'way of doing things'. It also involves a greater concern with its sustainability, and engagement in questioning what schools, driven by the English National Curriculum and tests, gain and want from this type of STEAM project. This stage is obviously helpful for our own discussion of STEAM curricula. As well as being concerned with *The Imagineerium*'s distinctive pedagogy, it is also concerned with its distinctive contribution to educational outcomes (including STEM) and the articulation of such outcomes with the demands of a national curriculum framework.

This stage of emulation grows out of two earlier stages of *emergence* and *experimentation*, both of which are significant in understanding the kind of project *The Imagineerium* has become. We use the term 'experimentation' in ways that reflect both science's commitment to systematic testing and trialling of ideas, and the arts' commitment to exploring the possibilities and potentialities of this form of

educational practice. The 'emergence' of *The Imagineerium* can be traced back not to educational activities, however, but to two distinct STEAM practices.

The first of these practices *emerged* from the needs of a cultural organisation, staging ambitious performance work. A seminal moment occurred when, in realising a community interpretation of The Mystery Plays, an approach was made to local engineers to create the sense of a 'flood' by having water gushing into the ruins of Coventry Cathedral. The engineering skills required were complex and formed an ongoing and productive relationship between the artists and the engineers. A second moment came when, as part of the Cultural Olympiad program in 2012, this team won a bid to realise a 6-metre-tall mechanical Godiva who would both walk and be cycled. The project drew on previous relationships, as well as developing new ones, between artists, engineers and local young people. The final animated sculpture drew on Coventry's historical association with both the story of Lady Godiva's protest in favour of social justice, and its association with bicycle manufacture. The walking structure of Godiva was animated by a battery driven car which operated a series of levers, wheel and cog systems for legs, arms and head, as well as electronic system to move her eyes. She could be standing or seated on her mechanised 'horse' and could be cycled by 30 tricycles. Her 'horse' could also be raised from seating to full height by one cyclist on a static bike using a gear system to mechanically crank the 'horse' up to greet the standing Godiva. As well as being a homage to Coventry's past, Godiva also carried the hopes and dreams of Coventry's young people of the future. The project combined a commitment to the arts in the community, as well as to engineering excellences, and involved a detailed 'working together' of all the partners involved. Thus, *The Imagineerium* emerged out a series of commitments to the local area, its present and historical commitment to engineering practices, and to community arts practices as a means to bring people together for a common purpose. It required a series of close relationships between engineers, engineering companies and local artists. Further, it was facilitated by a series of external, contingent, features in Coventry, particularly a recent history of educational innovation through the arts (see Creative Partnerships, n.d.). This model for developing educational activities through arts was valued, and the necessary expertise to support it was available locally. Out of this *Imagineerium* partnership emerged the desire, supported by local employers, to inspire a new generation of imaginative engineers and designers, as well as more broadly, to raise aspirations and develop positive learning behaviours for children in Coventry schools.

These educational purposes were realised through the development of *The Imagineerium* project led primarily by artists with experience of working in the community and with schools, but with the significant involvement of engineers, academics, and school teachers. This entailed an extended period of *experimentation* which explored, and responded to, a number of tensions, including:

- Commitments to STEM, especially engineering education, and to broader educational outcomes;
- Commitments to the arts as a site where human sociality, creativity and potential are valued and promoted;

- Involvement in an immersive and responsive STEAM project, and the need for mapping to national curriculum outcomes;
- Developing knowledge, habits of mind and the ability 'to do';
- Embodied, physical and active learning and theorised reflecting and understanding.

Whilst the 'shape' of *The Imagineerium* has changed during this process of experimentation, certain features have crystallised. Significantly, *The Imagineerium* has established a common, shared purpose and aims, and an eclectic approach to pedagogy, reflective of a flat, loosely coupled organisational hierarchy. It has also drawn on the specialist perspectives of the non-teaching partners in focusing on presenting pupils with 'authentic commissions' as the central feature of *The Imagineerium*'s approach to education. The authentic commission means that pupils are invited to design and prototype a specific object which requires the combination of engineering and artistic knowledge and abilities. The appeal of the invitation and the possibilities it affords is evident in the imaginative launch by costumed 'Imagineers', through a dramatised scenario in which they are in need of children's ideas but also communicating strong belief in the children's potential capabilities. Such authentic commissions are similar in type to the kinds of engineering/arts projects undertaken by professional artist and engineers. They are the kinds of commissions that first drew artists and engineers together in that emerging stage of *The Imagineerium*. Pupils are expected to be 'imagineers', who are doing 'real' engineering, design and technology with 'real' engineers, designers and technologists to develop imaginative artefacts. This model emphasises the specialist skills of the engineers, designers and technologist to support pupils' abilities to be designers, technologist and engineers which is united with artists' abilities to facilitate pupils' exploration and problem solving. In part this is through bodily/embodied experience of the physical properties of materials, how mechanisms work, and a range of other scientific knowledge. The teachers, usually not content specialists, bring a knowledge of the pupils and of the educative nature of the task. Thus, the experience is authentically real, not only in relation to the task, but in engaging with specialists in the field to shape not only the task but practical ways to respond to it. It is also an educative task, understood by all involved, but underpinned with the specific responsibility of the teachers who are, increasingly as the project moves from experimentation to emulation, also modelling being learners and facilitators in these STEAM practices. This is unlike other STEAM projects where teachers 'hand over' the pupils to STEAM experts for a short while. Here they co-plan and retain oversight of the learning, behaviour and well-being of their pupils. The model is also clearly mapped to the national curriculum expectations for their pupils, and it is in this regard we note the significance of academic educators in supporting teachers and *The Imagineerium* leadership to mediate between two different framings of STEM education. Curricula forms based in 'knowing how' and 'knowing that' are held in tension.

Trowsdale (2016) has more to say on the institutions, people and pedagogical principles of this experimental stage of *The Imagineerium*. However, we conclude this paper by considering the implications for our previous discussion of curriculum and practice as an anchor point to our consideration of the STEAM literature.

5. Addressing curricula issues in STEAM

Whilst the STEAM literature reviewed by Colucci-Gray et al (2017) was dominated by pedagogical concerns, we have noted a range of claims about how knowledge is conceptualised, about thinking and working beyond monodisciplinary silos and a concern with explicitly axiological, specifically postnormal and posthuman, conceptions of science. This latter issue reflects concerns with sustainability, with a focus on the needs of the economy as a driver for STEM education, and more generally questions as to the purpose of schooling. Alongside this we have noted a concern that STEAM education *ought* to view the arts as more than simply a handmaiden, and pedagogical device, for delivering interesting and creative STEM education. We have also argued that curriculum theory ought to be concerned with both educational foundations and with the practical needs of curriculum designers and teachers. In drawing these themes together we will focus on three aspects of *The Imagineerium*, before making some more general conclusions. The three aspects are: the inherent and negotiated instability of its underpinning knowledge foundations, its relationship to thinking and working beyond monodisciplinary silos, and its value commitments and axiological perspective in relation to conceptions of science, and to education more generally.

We add as a brief caution that taking a 'normative case study approach' has dangers in drawing us from reporting on *The Imagineerium* to commentating upon it as illustrative of wider debates. Thus, whilst we seek to retain an authentic representation of that project, we are aware that at times we point to aspects which, whilst clear to us through being enmeshed in the literature and different examples of practice, may not be the view of *The Imagineerium's* participants. The more general claim we make about curriculum theorists needing, Janus-like, to look two ways applies also in our particular case.

5.1 The Knowledge foundations

We noted in our discussion of *The Imagineerium* that there is an ongoing tension between a view of the practice as underpinned by 'knowing how', specifically knowing how to enact the practices and apply the knowledge of an engineer, and 'knowing that'. For example, knowing how to act out and physically sense the forces at play in a machine, and 'knowing that' forces operate on and in machines. This echoes a point made in phase 1 of Colucci-Gray et al's review which identified an element in the literature on the embodied nature of knowledge. This included the tacit and visceral nature of the knowledge that enabled pupils to engage successfully in STEAM activities.

In *The Imagineerium* there is clear concern not only, with a curriculum structured by 'knowing how' but also with 'knowing that'. The educational experiences of the pupils are not only considered and structured in terms of 'knowing how' to do things, but also mapped and shaped by the knowledge that pupils are expected to acquire. Government, via schools and teachers, require that the outcomes of *The Imagineerium* can be largely expressed in terms of 'know that' statements in order to align such learning with the national curriculum. Further teachers utilise time in the classroom to 'draw out' and restructure what

pupils have learnt in ways that dovetail with the kinds of learning outcomes expected in schools.

We have noted that these two views are in tension, neither subsuming the other. An aspect of the partnership with teachers is that teachers do not view learning in *The Imagineerium* as merely fodder for their educational endeavours, and *The Imagineerium* take seriously the need to be shaped by, and reinforce through reflection, the 'knowing that' which the school curriculum requires. Equally, the artists and engineers involved in *The Imagineerium* are collaboratively engaged in seeing what the distinct contributions of the arts and engineering might be, as well as considering the knowledge, both 'that' and 'how' which belongs to 'imagineering' as a complex hybrid. The 'form' of the knowledge which drives the construction and practice of *The Imagineerium* is not static, but in a state of intelligent evolution through discussion between the various stakeholders: teachers, engineers, artists and pupils themselves.

We also distinguished, in relation to *The Imagineerium's* emerging curriculum, between the 'form' of knowledge that structures it and its 'purpose'. Whilst there is inherent dialogue and evolution which constitutes a dynamic or an instability in the project with respect to *form*, there is a shared and collective agreement as to the *purposes* of *The Imagineerium*. The first is that pupils should take part in the kinds of exciting and complex activity that drew the community artists and the engineers together in the first place. The history of *The Imagineerium* is not just a statement of how it emerged, but has the power of a 'creation myth' into which teachers and pupils are initiated. Central to this myth is the mechanised figure of Godiva, who represents not only an arts/engineering hybrid, itself representative of the city, but also whose mythical role was/is to carry the hopes of the young people of Coventry. She symbolises and embodies the possibilities of *imagineering*. The second is that learning engineering/imagineering (as opposed to learning about engineering/imagineering) is best understood within a real context, not just one that offers a simulacrum of reality. Thus, pupils' experience of *The Imagineerium,* whilst cloaked in a dramatic story, nevertheless involves them exploring, designing and developing an artefact for a real commission with the expectation that some of those designs will be built and utilised in public spaces. Learning occurs for pupils because it is needed for the task at hand, rather than the task at hand being designed for learning to occur. This second purpose draws into sharp relief the tension in the project between 'knowing how' and 'knowing that'; it requires great foresight (perhaps 'second sight') to identify the knowledge which will emerge from the open pursuit of real commissions. The fact that it can be practically achieved shows that although theoretically distinct, coherent educative experiences can be simultaneously viewed through both lenses of both 'knowing how' and 'knowing that'.

What seems to underpin *The Imagineerium's* practice is an assumption that by introducing pupils to what *the adults* do and how they do it, what will emerge is an understanding of the knowledge ('that' and 'how') that is useful to those adults, as well as an understanding of why. It is an apprenticeship into a set of living and evolving activities which are deemed worthwhile. The instability of the conception of knowledge is held productively, we argue, by two aspects. The first is ongoing dialogic involvement of artists, engineering, teachers and educators

who are in a process of reviewing and considering the ways in which the project contributes to the development of pupils. The second is this shared commitment, symbolised by Godiva, to the value of a real, authentic commission reflective of the arts/engineering hybrid that formed *The Imagineerium* itself.

5.2 Moving beyond monodisciplinary thinking and working

In the review, moving beyond monodisciplinary thinking and working was deemed to be important and a significant justification for the STEAM agenda (see Colucci-Gray, 2017, p. 31). Examples of higher education STEAM projects, identified in phase 2 of Colucci-Gray et al's review (2017, p. 43), suggest the desirability of a focus on the ways that discipline specific undergraduate students are enabled to see their own disciplines in a new light, as well as gain insights into other disciplines[5]. There is also evidence in the literature of improved working together. These are two aspects of working and thinking in inter/transdisciplinary ways (see, for example in relation to art and engineering, Guyotte et al, 2015).

On the surface it would seem that The Imagineerium ought also to be seen as an interdisciplinary and perhaps transdisciplinary project, however, this is not the case. It does not need stating that the primary aged pupils involved in *The Imagineerium* do not have a level of disciplinary specific knowledge either to ground their thinking, nor to cloud it with disciplinary presuppositions. Whilst the pupils gain and speak of new insights into how the arts and sciences relate, it is clear that in *The Imagineerium* they are not acting in transdisciplinary ways, but drawing from and combining skills and knowledge from different disciplines. The real commission, which constitutes the pupil design task, requires insights from a number of disciplines, but where transdisciplinary thinking and working is happening it is the activity of the engineers and artists who are 'the commissioners' for the pupils' projects.

We think, therefore, that we need to be careful about the direct ascription of transdisciplinary (or in fact multi or interdisciplinarity) as a necessary feature of a STEAM project in which the arts are more than handmaidens to STEM. It is inviting to make such a claim, but the 'who' and 'where' of transdisciplinarity working is important. In *The Imagineerium* the adults design the real educative commissions as a result of transdisciplinary ways of working together. The pupils are therefore exposed to the outcomes of transdisciplinary thinking and working, but their experience is not in itself transdisciplinarity, In fact it is best viewed not as *disciplinary*, but as experiences of engineering *practices*.

5.3 Axiology, science and the purpose of education

As Colucci-Gray et al note a recurring theme in the STEAM literature is the place of values in relation to STEM education. Some authors have identified the addition of the arts as an effective means to redress perceived deficits in STEM education practices. In relation to our analysis we note that these particularly relate to issues of sustainability and the perceived uncritical application of science and technology in the service of neoliberal projects. Colucci-Gray et al identify the frequent discussion of these issues in the light of contemporary

debates in the epistemology of science, specifically the rise of postnormal and posthuman science. It is worth marking a distinction, which is difficult to see in the literature itself, between claims to the 'form' of a conception of science which is alternative to the one that dominates contemporary practice, and claims about the 'purpose' of STEM education.

The first foregrounds postnormal and posthuman conceptions of science which are framed in terms of a systematic account of values, that is they are inherently axiological. The second foregrounds political values such as sustainability, governance and economic principles, which are reflective of the values of the educators and educational institutions involved. In the state sector in the U.K. the establishing of a broad range of socially agreed human values has proved difficult [see SCAA, 1996; also the debates in 'British Values' (see DfE, 2014; Curren, 2017)].

The Imagineerium, grounded as it is in the community arts, expresses a core value in the centrality of human beings (both individually and collectively). This is not only expressed in the view that technology and engineering can be used for human good, but also that engineering offers an opportunity for the creative expression of inherent human qualities. Further, a significant aspect of *The Imagineerium's* approach to learning is through the human body. It is worth noting, in terms of the educational purpose of *The Imagineerium* there is no claim to axiological consistency. It may be that one value might exist in tension with another expressed by the project. In practical contexts informal processes of 'reflective equilibrium' (Daniels, 2016) usually resolve any particular conflicts internal to the project.

What is clear is that this centring on humans (*pace* Colucci-Gray et al's claim) is not reflected in posthuman and postnormal conceptions of science, at least as they impact on the STEAM literature. This decentring of the human is shared, interestingly by neo-liberal and late capitalist models of science (see Lewin and Lundie, 2016 in respect of digital technologies). It is therefore not surprising that we see little evidence of *The Imagineerium* engaged with, or interested in, new conceptions of science. *The Imagineerium's* commitment to the human, which emerges historically from its partial origins in community arts where it is a dominant feature (see Meade & Shaw, 2007), reflects its hybridity as an engineering/arts project. It is not simply promoting engineering, design and technology in the interests of humans, but that the process of design and engineering can be approached and conducted *humanly*. When fused with other values, such as a commitment to the place of Coventry and its population, we see a focus on, amongst other things, sustainability.

6. Conclusion

We started this paper to 'make sense' the aspects of a recent review of STEAM education which were not simply pedagogical. Three repeated features of that review was a tendency in STEM education to see the arts as a handmaiden, to retain a monodisciplinary focus, and not to question dominant conceptions of science. The literature on STEAM seeks to respond to these issues, as well as make contributions to more effective forms of STEM education. We explored these issues through a single case of an arts/engineering hybrid

project, treated 'normatively'. In conclusion, we make three claims concerning STEAM education which are significant for theorising about such curriculum.

Firstly, whilst there may be good reasons to reject certain structuring conceptions of knowledge, there is no necessarily for STEAM education to resolve the tensions between 'knowing how' and 'knowing that'. Whilst 'knowing that' has dominated STEM curriculum in the UK, this is not the case in the arts when 'know how' retains a significant place. A hybrid model of STEAM education, such as *The Imagineerium*, can live with this instability of structuring principles through ongoing dialogue between the different participants, and through agreement on the central purposes of the educational activity. We conclude that where a project begins with questions about 'how the arts can contribute to STEM education' the likely outcome is that the arts becoming a handmaiden and pedagogical tool. At least in school based education, the interdisciplinarity needs to be consolidated at the level of educational foundations. The project, that is, needs to be a hybrid of the STEM subject and the arts. The dialogue and collaboration between artists, STEM practitioners, teachers and educators needs to occur in detail about their practices, both in designing the project, and as an ongoing feature of the work with pupils. Such dialogues need to clarify purposes for the project which are shared and embraced by those involved.

Secondly, although educational foundations are related to academic disciplines, STEAM implies a rethinking of the disciplinary framing of contemporary UK curriculum design. If an educational intervention is to reflect a notion of STEAM in its *form*, then the thinking and working underpinning that intervention must move beyond monodisciplinarity. We have noted that in educational activities this can be developed in different ways, depending on the purpose of the activity. In those cases, usually in higher education, where the purpose is to enable *students* to move beyond their disciplinary perspectives to develop the ability to work in interdisciplinary and transdisciplinary ways, STEM practitioners and artists are required to work beyond monodisciplinarity. In the case of *The Imagineerium* this is not the purpose of the educational activity, it is the educators rather than the pupils that are required to move beyond monodisciplinarity. There are implications here for school based school activities where the resources of STEM practitioners and the artists with experience of working in this way are not typically available.

Thirdly, a rolling theme in this paper is the question of purpose. Colucci-Gray et al (2017, p. 13ff) see one reading of much of the STEAM literature as a site of critique of present practice. These included dissatisfaction with pedagogy and with STEM content. A third dissatisfaction was with the purpose of education in general and with STEM education in particular. We have argued that purpose is one of the key features that 'stabilizes' *The Imagineerium* and allows it to handle the tensions between two competing structuring principles in 'knowing how' and 'knowing that'. The two different purposes identified in the STEAM literature were a concern with preparing pupils for STEM careers, and enabling them to be informed citizens in our society. Both of these have been shaped by concerns that real world problems require more than monodisciplinary thinking. As we have argued from *The Imagineerium*, STEAM projects do not require (and perhaps never can at school level) pupils to work or think in interdisciplinary or

transdisciplinary ways, but to engage in a hybrid educational project. It remains an open question as to whether such experiences contribute to the ability of pupils to work in such ways later in the educational careers. In the STEAM literature there is a critique that that education ought not to be concerned solely with employment, and an expectation that this tendency towards employability evident in STEM education will be ameliorated by the inclusion of the arts. This is, however, another view of 'the arts as handmaiden', in which the arts are deemed to be able to cover a deficit in STEM education. Central to *The Imagineerium* are not distinctively STEM/STEAM purposes, but a concern that education ought to be 'human centred'. This emerges not exclusively from the arts, but from a shared purpose amongst artists and engineers. Whilst the reasons for valuing human centeredness differs in the different disciplines, there is shared agreement on its importance.

STEAM education, in its literature and practice, is an emerging area of research and discussion. Whilst it is rhetorically significant, it is less clear how one is to make sense of it, and in what way it can contribute to our understanding of education practice. In this paper, by focussing on one case study in the light of a broader review, we have sought to identify and explore a number of key aspects which emerge from contemporary discussions. It is an issue that is in need of further analysis, but we conclude with two comments. The first is to reject an easy acceptance of STEAM as reflecting the changing requirement of the economy for interdisciplinary and transdisciplinary working, or a simple critique of this position. The issue has a greater depth and nuance than such stability engenders. The second is that projects like *The Imagineerium* exemplify the value of spaces and times for STEM practitioners, artists, teachers and educators to engage in critical dialogue about the purposes and form of STEAM education, and to develop their own understanding of working and thinking beyond monodisciplinarity.

7. Notes

1. The authors were members of this research commission.
2. The term here draws upon its use by Disney.
3. We note that appreciative knowledge such as that outlined by Reid (1976) as 'knowing this' offers an additional and potentially fertile further paradigm for exploring the knowledge and sensibilities that the arts bring to education. However it is beyond the scope of this article to do justice to such an exploration.
4. The term 'form' fits with Hirst's idealist presuppositions, but we use it here in a broader way to identify the conceptualisation of epistemic landscape.
5. The literature is limited to US higher education programmes, although there are similarities in UK programmes of inter-professional education (see for example, Carpenter and Dickinson, 2016).

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