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The culture of disciplines: Reconceptualising multi-subject curricula

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The arts are recognised for their potential to humanise and enrich educational experience, but hold a lowly position in the hierarchy of school subject-based curricula. This limits the time, and thus the influence, they can have. Whilst schools welcome the idea of a curriculum rich with both arts and science subjects, resistance to realising this is often advanced in terms of the proportion of curriculum time required for different subjects. Arguments for STEAM education, whilst apparently challenging this and valuing the potential of the arts, have reinforced its servant role. Drawing on research into a particular project, where the perspectives of the arts and sciences inform and enrich how the other is experienced and understood, we reframe this problem. Firstly, drawing on Massey's conception of space-time, we argue that one can conceive of more than one subject occupying the same curricular space on a school timetable. Secondly, informed by Geertz, we consider what the culture of the arts and the sciences offers, suggesting that this appears to reflect what teachers have valued. We argue that foregrounding the culture of school subjects, and particularly the culture of the arts, as part of a multicultural frame can facilitate rich and engaging educational experiences. Rather than being positioned as competing for time or status in the curriculum, a focus on culture emphasises how the co-existence and interplay of multiple subjects broadens, develops and thus enriches children's educational experience. It also enables a different conception of, and thus role for, the arts in schooling.

Keywords: culture; curriculum development; *Imagineerium*; professional development

Introduction

The Imagineerium was a 5-year primary education project at the frontiers of arts and engineering, funded by Arts Connect and the Paul Hamlyn Foundation. The project involved artists and engineers working with children and teachers in both school and arts-engineering locations (see Trowsdale, 2020). *The Imagineerium* inspired teachers and prompted a desire to develop '*Imagineerium*-like' practices in their schools as part of the everyday timetable. Teacher interviews identified that the project was seen as novel, somewhat outside of the normal curriculum, and thus not expected to conform to everyday teacher and pupil expectations. An aspect of this was the way the curriculum was conceived differently to that usually seen in schools; with the school curriculum commonly being conceived as time segments divided into individual subject[1] lessons. This conception appeared to be a significant conceptual barrier to the

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realisation of the teachers' desire for developing the perceived advantages of '*Imagineerium*-like' practices in their schools. This difficulty is not one solely experienced by the teachers in *The Imagineerium*. We saw the same issues reflected in our review of Science, Technology, Engineering, Arts and Mathematics (STEAM) education (Colucci-Gray *et al.*, 2017). The review reported examples of practice, featuring one art form in relation to one or more Science, Technology, Engineering and Mathematics (STEM) subjects. In almost all examples, the art form played a servant role in supporting the outcome of that STEM subject. This is not surprising, given that the impetus for much use of the arts is to motivate pupils' continued engagement and learning in STEM, but this purpose is also a limitation.

Our current research into an *Imagineerium* legacy project, *Teach-Make*, supports seven primary schools to develop schemes of work following the model of *The Imagineerium*. As part of the development of this project we have sought to identify ways of conceiving of the relationship between STEM and arts subjects that overcome this 'servant' relationship. In this article we explore the need to help teachers conceptualise the space and time of the school curriculum differently, and thereby their approach to the design of educative experiences. Our approach draws upon Massey's conception of space-time, and upon Geertz's conception of culture. These inform our conceptualisation of how '*Imagineerium*-like' educative experiences operate and how they are dissonant with the dominant perspectives of the participating teachers, who generally conceive of curriculum in terms of single, bounded, subjects of knowledge and related skills.

We argue that teachers' dominant curriculum discourse is limited by a conception of curricular space-time,[2] founded on a view of the curriculum as composed of a series of discrete subjects. Each discrete subject takes up its own 'space' in the school timetable to the exclusion of all others; two school subjects cannot, therefore, simultaneously occupy the same curricular space-time. The issue is not a matter of the political value of school subjects per se, or of the conception of the curriculum, but rather its 'taken-for-granted' spatial and temporal organisation. Even in topic work, which involves more than one subject, teachers tend to see themes and topics as context for exploring and developing specific subject knowledge, and related skills and habits. We articulate this as a Newtonian conception of space-time, in which only one 'thing' can occupy the same space at the same time. Massey (2005) distinguishes this from a quantum conception in which it is possible for multiple 'things' to occupy the same space-time. The 'things' in this case being particular subjects. Appropriating Massey, we argue that a 'quantum space-time' conception of the curriculum underpins *The Imagineerium* and has importance for STEAM education.

In order to develop this account of quantum space-time appropriate for STEM and arts hybrid curricula, we explore the distinction between activities and the way we give meaning to those activities. We mark this as a distinction between 'form' and 'culture' (see Trowsdale, 2018), drawing on Geertz's (1973) semiotic conception of culture. In this article we argue that the form and content which characterise and partially define particular subjects can be accessed and richly illuminated using different, multiple yet distinct *cultures*, in our case the cultures of 'science' and 'arts', simultaneously. This multicultural perspective allows for a quantum model of curriculum

space-time and enables a way for teachers to conceive of STEM and arts subjects to be equal at the same time in the same space.

Whilst these conceptions inform the problem of developing teachers' conceptions of curriculum, we also note the importance of iterative, imaginative and embodied practice, to affect such a paradigm shift, as noted by Steiner and Kersting (2019). We conclude by suggesting that the concepts of 'space-time' and 'culture' form a useful framework for addressing the professional development issue of helping teachers to move from a Newtonian to a quantum conception of the curriculum.

It is worth noting that we are not in this article seeking to defend STEAM education, nor the value of the arts per se. In practice, both of these are already largely accepted by teachers, and certainly the teachers in *The Imagineerium* and *Teach-Make* projects. Instead, our focus is the difficulties around *enabling* arts–science quantum curricular space-time *to be seen as possible* in schools. We begin with a brief review of the STEAM agenda and particularly *The Imagineerium* project, before moving to consider Massey's argument in more detail. We then develop the meaning of a quantum conception of curricular space-time by considering the distinction between the 'culture' and 'form'. In the final section of the article, we develop the implications of this analysis in identifying a broad approach to supporting teachers' development in thinking in more 'hybrid curriculum' ways. We conclude by arguing that, whilst this does not address all the difficulties of the role of the arts in STEAM, nevertheless it offers a substantial redescription of this problem with significant advantages for educational practice.

The role of 'A' in STEAM education

STEAM education has risen up the research agenda in recent years (see Yakman, 2010, 2017; Colucci-Gray *et al.*, 2017; MacDonald *et al.*, 2019; Perignat & Katz-Buonincontro, 2019; Mejias *et al.*, 2021). There are a number of different justifications for the inclusion of the arts in the more familiar STEM acronym, reflecting a range of practice and ideological reasons. These include: as a response to economic demand for a larger STEM workforce (Segarra *et al.*, 2018; Thomas & Huffman, 2020); as a way of offsetting the marginalisation of the arts in education (Cultural Learning Alliance, 2017); given the need to rethink the role of science education from more environmental and post-human perspectives; given the need for more creative pedagogies in schools; and with the view that some elements of the STEM agenda were always aligned to more art and design principles (see Colucci-Gray *et al.*, 2017). This latter review noted a lack of consistency in the use of the term STEAM, reflecting different conceptions of STEAM-related practice and different accounts of the primary purpose and role of the arts in STEAM. It took a relatively inclusive position, noting a spectrum of work spanning creative STEM projects through to those with a more integrated approach to STEM and the arts (e.g. Guyotte *et al.*, 2015; Trowsdale, 2016). Creative approaches focused on 'motivational science' experiences where pupils are inspired through spectacular, playful, visual and fun approaches. Teacher comments gathered during the STEAM review (Colucci-Gray *et al.*, 2017), our work on *The Imagineerium* (Trowsdale, 2020) and early interview data from *Teach-Make* consistently indicate that these inspirational and motivational

pedagogies approaches do indeed pique the interest of pupils in science, which is their primary aim. (Although there are differences here in relation to some key issues such as gender; see e.g. Archer *et al.*, 2013). Whilst a by-product of such approaches may also result in an experience of arts practice, the role of the arts in such creative practices can clearly be identified as a 'servant' to the primary educational aims of developing STEM knowledge and interest. This servant role is problematic, we believe, because it prevents a genuinely broad and balanced experience of education.

The review recognised *The Imagineerium* as one of the limited number of STEAM projects which has undergone systematic evaluation (see Trowsdale, 2016, 2020; Trowsdale *et al.*, 2019)[3] and in which a different dynamic and equality was evident between STEM and arts disciplines. *The Imagineerium* is a partnership between community arts practitioners, engineers and teachers, supported by educational researchers, which integrates engineering and artistic practices. The project involves primary school children working alongside 'imagineers'[4] (artists, engineers and educators) on a commission: to imagine, design and make models of kinetic artwork. This appears, from the outset, primarily an art-making activity, but one dependent on and interwoven with engineering expertise. Prior to the project, the imagineers involved had formed a new community of practice through their own experience of developing culturally significant hybrid art-engineering projects, most notably as part of the 2012 UK Cultural Olympiad (see www.imagineer-productions.co.uk/godiva-awakes/). Following discussions with engineering companies, education leaders and teachers, the partners developed a collective understanding of how the arts and physical sciences can be jointly pursued to support and expand pupils' education. This was realised in *The Imagineerium*, an educational intervention running from 2014 to 2019. Imagineering foregrounds the embodied nature of practice, facilitating the development of ideas through drawing, drama and other hands-on making activities. It reflects both the professional practices of imagineers and an intentional experiential pedagogy.

One of the projects for pupils was to design and create a part-working model of a mechanical, moving artwork to be built as part of a local art trail. This was a real commission in that a proportion of the models would be built and installed. The sculpture was to represent a significant event in Coventry's history. During the development of the working model, pupils engaged in physical theatre to re-enact the historical event, learned about scientific concepts and worked out the mechanisms which would enable the design to move in the desired way. In planning their designs, children both drew on engineering for the mechanics and generated artistic representations of 'how it would look'. They engaged in telling the story, and in presenting the details of their sculpture to a group of (adult) engineers, civic planners and artists who were choosing which of the sculptures would be built to full size by local companies. Pupils needed to develop and deploy integrated abilities and knowledge in science, and specific art forms to produce an engineered piece of art. If the mechanics did not work then the design would not work, but also it needed to 'tell the story' and be aesthetically valuable. All aspects were needed if the sculpture was to meet the standards required.

In another project, one group of children were struggling to agree on how their 2D design idea could be realised. The internal structure for the first 3D prototype reflected an early 2D drawing of a straight tubular trunk. This first 3D model neither looked like a tree nor offered the functionality that they had hoped for in terms of

allowing other mechanical animation to project from the trunk. The chance discovery and exploratory manipulation of a piece of vent hosing generated awareness of the properties of thin-wired concertinaed circles, which were flexible enough to be twisted, stretched and alter the shape of the original tube. This haptic experience was crucial in developing their design. The experience of touch and sight of the behaviour of this material suggested possible qualities of a tree trunk to their imaginations. As they explored, they could see how openings could be created to house other mechanical devices—from which birds and 'fruit' could emerge. Here, tinkering with the properties of materials, whilst holding the sketched and imagined designs in mind, prompted a simultaneous and hybridised subject experience which stimulated pupils' awareness, judgement and learning.

Teachers welcomed *The Imagineerium* both for its benefits for pupils' learning in science as well as for developing confidence in their capability as learners more broadly (Trowsdale *et al.*, 2019). Both kinds of benefits, plus the value of addressing a range of subjects, stimulated the appetite to develop ongoing school-based '*Imagineerium*-like' approaches. However, interview data with teachers showed that whilst they saw the value of these hybridised curricula approaches, and wanted to use them, they found it difficult to conceive of how this is possible in mainstream schools (Trowsdale, 2020). The practical result was the *Teach-Make* teacher development project, as a legacy project of *The Imagineerium*.

In discussions of early iterations of *The Imagineerium*, teachers identified a need for more knowledge and skills in arts-engineering practices (Trowsdale, 2020). Hence, the professional development sessions during *The Imagineerium* had addressed these concerns and developed greater confidence in the processes, knowledge and equipment. However, addressing such expertise alone has only occasionally resulted in teachers initiating '*Imagineerium*-like' practices. It appeared that they found it difficult to see how it could be part of *their* school's curriculum, especially how one conceives of a curriculum in which two subjects occupy the same lesson slot. Teachers had, up to this point, been introduced to the ideas in *The Imagineerium* through examples of practice and ostensive definitions. What was needed to support teachers' understanding and practice was a more refined development of the concepts and ideas that underpinned this approach (Trowsdale, 2017). Such a refined discourse needs to respect 'imagineering' practice as *fully and simultaneously* engineering and art, and the language that teachers use to express their normal practice in relation to curriculum design (see e.g. Pring, 1975; Davies, 2016). What is needed is a more nuanced, educationally relevant articulation of the 'how' of the integration of engineering and the arts.

We now turn to discussing those distinctions. The first articulates two conceptions of space-time, which expresses the shift from single to multiple occupancy of space. The second enables us to focus on *meaning* in relation to subject areas, which enables us to transcend teachers' focus on the activity of those subjects.

Conceptualising curricular space-time

As well as conceiving of the possibility of hybridity, one needs to consider the school context, and specifically why conceiving of the curriculum in this way is difficult for teachers. We consider this through the lens of Massey (2005). She identifies two

distinct conceptions of space-time drawn from different models of natural science: the Newtonian and the quantum. She argues that Newtonian conceptions of space-time imply that only one social group can occupy one space at any one time:

> In the hands of ideologues such a time concept is easily transformed into a kind of political physics. After all, it is not difficult to transpose from physics to politics one of the most ancient rules which states that it is impossible for two bodies to occupy the same space at the same time. (Fabian, 1983; quoted in Massey, 2005, p. 73)

She argues:

> It is an essentialist, billiard-ball view of place... It runs clearly against the injunction that space be thought of as an emergent product of relations, including those relations which establish boundaries.... (Massey, 2005, p. 68)

Newtonian space-time, understood in relation to social groups, is necessarily exclusionary, one group's occupation of space necessarily excludes others, and often engenders hostility and conflict. She draws on the example of the conquistadors and their engagement with the indigenous population. The conquistadors cannot conceive of shared space for both them and the people whose land they invade. One can see similar concerns in the public rhetoric of the ways young people monopolise the public space of the street, making it 'unsafe' for adults. If one group occupies the space then, in this rhetoric, other groups are excluded. The Newtonian conception treats social groups as hard objects that 'occupy space' as groups and not only as individuals. By comparison, the quantum conception of space-time treats social groups as 'waves', which can happily co-exist and even interact in the same space-time.

There can be no doubt that the contemporary school is conceived in terms of 'times' and 'places', as reflected in Foucault's (1991) rather dystopian vision. Drawing on Massey's distinction between *Newtonian* or *quantum* conceptions of space, school curricular space-time can be conceived as either being fully filled by a single curriculum subject, or as being 'open', amenable to being 'filled' by multiple subject areas and perhaps transcending all of them.

Space-time in the school day is perceived, in the form of a social imaginary, by teachers and pupils as relating to specific areas of the curriculum, and the dominant model in schooling is of particular subject areas informed directly by the academic disciplines (Science, Mathematics, English, etc.). It is possible that curriculum space-time can be seen differently, in terms of different subject areas, or multi-subject areas (see e.g. Holland & McKenna, 2005). There are also examples of integrated or topic-based curricula, though these remain rare in recent English compulsory education (tellingly indicated by the omission of England from Kneen *et al.*'s, 2020 recent analysis).

Our contention in relation to teachers and their conception of curricular space-time is twofold. Firstly, that teachers *tend* to see such space-time primarily in *Newtonian* terms. This is not to say that this is inevitable, or that teachers cannot conceive of curriculum space-time in different ways. Secondly, when teachers do conceive of curricular space-time in more *quantum* ways, this is usually in projects outside of their classroom, viewed as exceptional to the norm, as 'off curriculum' time. For example, *The Imagineerium* is identified by teachers as a unique and exciting project involving the arts and the sciences (Trowsdale, 2020), but this uniqueness comes at the cost of

seeing it as 'other', as outside of school space-time, even if it occurs physically in the school and temporally during the school day.

In this article, we accept this as an empirical assumption (but see Trowsdale, 2020 for evidence to support this) and claim that the in-school lives of both teacher and pupil are dictated by the physical spaces they need to occupy at particular times, which in turn constructs a particular psychic space and habitus (Bourdieu, 1990). The effect of this influence is that each finds comfort in knowing that they are occupying the correct space-time. For pupils, the punctuation of space-time is perhaps most explicit in the language of secondary education where it is no longer, for example, 2 p.m. but the middle of fourth lesson, and one is not in a room but specifically the history classroom (or science laboratory, etc.). For the primary school teacher, space-time is punctuated by the structure of the curriculum, with classroom space being transformed as a response to curriculum time: it becomes a science laboratory, a mathematics classroom, etc. as the timetable dictates. The school day is divided into subjects and into specific bounded periods of time (lessons), which direct the attention and focus of both teachers and pupils. This is the *Newtonian* conception of school space-time in which two subject areas cannot occupy the same curricular space simultaneously. Thus, the teacher or pupils might, in the science classroom, utilise arts activities, but only in so far as they support the appropriate science education outcomes. The arts have a servant status.

On this account, moving from seeing the arts as only 'servant' would require a conception of curriculum space-time which allows multiple subjects to be seen and felt as equally salient and important for the learning in that particular space-time. We have elsewhere (Davies & Trowsdale, 2017) argued that one way to do this is to re-articulate the epistemic foundations of the curriculum and effectively displace a subject-based curriculum. This is partly seen in recent proposed reconceptualisations of curricula in UK jurisdictions beyond England and in Europe (see e.g. the Donaldson, 2015 review of Welsh education; Lähdemäki, 2019; the Scottish Government's, 2019 curriculum for excellence). However, whilst the invitation to construct curricula differently from the single subject-based model may be offered by policymakers, we suggest that the space-time habitus that dominates thinking ensures that such alternative conceptions of the curriculum are only exceptionally reflected in the practical curricula implemented by schools. Our provocation in this article is to develop the discourse around school space-time as a precursor, or alternative, to material changes to the education system focal in many critiques of curriculum innovation (Davies & Trowsdale, 2017).

Meaning and activity

Shifting from a Newtonian to a quantum conception of curricular space-time develops the potential for a hybrid curriculum; one in which different subjects can equally occupy the same space at the same time. We have set out the Newtonian, single-subject conception of school curricula, but the question remains: how can one conceive of a quantum curricular space-time? We argue that a practically viable approach, and one emerging from the experiences of *The Imagineerium*, is to focus on the different ways we give meaning to the activities of the classroom. In broad terms, by

distinguishing between the activity or 'form' and the 'culture' of the subject(s) explored in the classroom. The activities of the classroom are given meaning, that is made intelligible, by the cultural resources that we bring to bear on them. We are socialised, and in the case of teachers *professionally socialised*, to see some activities as 'naturally' belonging to a particular subject. It becomes 'natural' and 'normal' to draw on the monocultural resources of this one subject to give meaning, and pupils' engagement with those activities will be limited to thinking in terms of that one subject.

Where the cultures of a number of subjects are simultaneously deployed, then the activities of the classroom can be understood more 'multiculturally'. This requires the teacher to problematise the taken-for-grantedness of the relationship between particular activities and cultural resources. Clearly, there are limits, as more resources for meaning making do not necessarily improve intelligibility. As with any educative endeavour, there is a requirement (usually on the educator) to ensure a coherent experience. In the case of *The Imagineerium*, and hence *Teach-Make*, this coherence is grounded in a particular art-making community of practice, 'imagineering'. This community of practice is not uniquely positioned to underpin an intelligible subject-multicultural classroom, but we note that some such account must be given as the foundation of a hybrid curriculum. It is the fluidity of cultures to address themselves to a wide variety of forms, and to interpenetrate each other, that makes them suited as the foundation for a quantum conception of curricular space-time. As we discussed earlier, it is the interplay of the cultural resources of art-making and engineering that enabled children to extend their understanding of both in the context of an arts-engineering commission. Playing with the concertinaed tube enabled them to consider how to realise their art-making project of a mechanically animated tree and, simultaneously, develop a deeper knowledge of the properties of materials. Being forced into making sense of this as either art-making or engineering distorts the reality of the learning, and limits its potency for pupils.

Specifying the cultures of the arts and the sciences in general will not be straightforward; however, it requires identification of the general semiotic characteristics of the particular culture, in order to, as Geertz points out, 'rescue the "said"... from its perishable conditions' (Geertz, 1973, p. 318) and yet remain 'closely tied... to concrete social event and occasions, the public world of common life' (Geertz, 1973, p. 322). Such an analysis is beyond the scope of this article. However, given its focus on the significance of the arts, it is worth indicating what the culture of the arts brings to a more hybrid curriculum.

In considering what the culture of the arts brings, we draw attention to what is distinctive to the arts; namely, that in their central activity of *making* they are concerned to explore, interpret and symbolise ideas and experiences, and are embodied, relational and affective in the process. As artists explore and probe varied and specific emphases within their art-making practices, they deploy the natural languages/sign systems and materials of their art-form in physical and emotive ways. These are issues that have emerged from an arts-engineering project, *The Imagineerium*, but we would argue are also more broadly reflected in STEAM (see Colucci-Gray *et al.*, 2017) and arts education literature (Ross, 1989; Greene, 1995; Eisner, 2002). The proclivities of artists to express themselves through gesture, movement, drawing, making, etc. reflect the culture of the arts, where the material is understood in ways that draw

attention to the relationships between people, between people and materials, and between performance and observation. These issues have recently been explored through ideas in 'new materialism' (see Barrett & Bolt, 2013). Meaning is embodied, literally in the body of the artist, but also in a range of material entities: photographs, sculpture, redesigning space and non-space, etc. Now, of course these signs are often embedded in particular artistic forms, but also transcend such forms to reflect a culture distinctive to the arts. Use of the material, understood in this way, speaks with immediacy (to draw on Collingwood's, 1924 account of aesthetics). The signs and practices of the arts have a visceral aspect, the viscera of the artist speaking to the other/observer/participant.

Differences between the culture of the sciences and the arts is reflected in the different meanings implicit in key terms. For example, there has been some recent discussion of the use of the terms 'experiment' and 'experimental' in the arts and sciences (see Lapointe, 2015; Pickering, 2016). From this, and our experience of working with artists and engineers, we think a distinction can be made in the ways artists and scientists use the term. Artists experiment by testing out possibilities and seeing their effect. The precise nature and form of the experimentation emerges as the artist engages in it. In the sciences, the approach to experimentation is more structured, founded on the testing of predetermined hypotheses, even if open to the unexpected. Artists' approach to experimentation reflects a culture that values opening up possibilities, seeking the unexpected and the unfamiliar, pushing boundaries and doing things differently. This is not to say that it is unbounded; different artistic forms give boundaries to experimentation, but nevertheless novelty and possibility thinking are critical to the 'culture of the arts'.

Although compressed and limited, this account of what the culture of the arts entails is sufficient for the argument of this article. This semiotic account of the culture of the arts is identified in the work of artists, but seeps beyond that limited context to provide an 'imaginative universe'. This is a universe in which, to rework Geertz, acts can sign differently and in which new signs and new acts become significant. In setting out the argument in this way, we are looking to understand the role of 'the A in STEAM' in ways that do not make the arts a servant to STEM subject areas, but in which STEM and the arts can co-construct new ways of enhancing the education of pupils.

Moving forward: towards a practical response

Even if we are correct in the analysis of the problem, and the conceptual path to a solution, this still leaves us some way from a practical way of improving STEAM practice in schools. If changing the way teachers conceive of quantum curricular space-time in the way we have suggested were easy then it would, we suspect, have already occurred. As we noted earlier, it is not that teachers cannot conceive of hybridised education of this sort, but that it is not consistent with their taken-for-granted reading of particular forms in terms of a subject monoculture. Teacher data shows that their attempts at more motivating STEAM lessons reflect this belief that there is a better way (Trowsdale, 2020), but that they are without the conceptual apparatus to implement it effectively.

Steier and Kersting (2019) have reviewed an analogous situation in A-level physics teaching and identified approaches which also address our issue. Their article focused on the ways in which two students are trying to understand the relativistic conception of gravity. One of the students in particular consistently finds it difficult to articulate this conception of gravity without drawing on (the opposing) Newtonian account of gravity. The details of the difficulty and the detailed analysis of the students' discussion which Steier and Kersting present is unnecessary for our purposes. Rather, we limit ourselves to considering the similarities with our own situation.

Firstly, Steier and Kersting identify that this is a conceptual problem for both of the students who are searching to understand 'gravity' in terms of relativistic physics. The problem is, in part, grounded in the fact that the students already have a well-developed and taken-for-granted conception of gravity; the Newtonian account. The situation, they claim, is better seen as a process of *translation* as opposed to learning something new, and this has specific challenges for educators. Secondly, it is clear that both students have an understanding of relativistic physics and the concept of *spacetime*, as well as an understanding of Newtonian physics. The difficulty lies in shifting their conception of gravity from one paradigm to another, evidenced in their continual use of ideas from the Newtonian account in trying to give a relativistic account. Thirdly, the conversation between the two students in trying to conceive of gravity in relativistic terms is iterative and marked by 'a diverse set of imaginative activities that are strongly tied to communicative, cognitive and bodily action' (Steier & Kersting, 2019, p. 145). These included gestures, shared drawing and attempts to physically represent curved spacetime. Steier and Kersting's analysis focuses on the role of 'imagining' and 'metaimagining' as vehicles by which the students support each other to develop their understanding. For them, imagining 'shifts the concept from the realm of the invisible and mysterious to one that is visible and even central to some kinds of meaning…' (Steier & Kersting, 2019, p. 145). Metaimagining is the process of negotiating through gesture, drawing, etc. between two (or more) different imaginings of the same concept. Steier and Kersting argue that when imagining fails to represent the concept clearly, there needs to be a more explicit, iterative process of working through the different imaginings developed (in this case by the students). The process of translating from one conceptualisation of gravity to another has, therefore, two stages: the making visible in a process of imagining, and explicitly considering the ways in which different imaginings are explored and translation achieved.

In a similar way to Steier and Kersting's students, our situation is that teachers need to translate from one conception of curricular space-time to another. Through *The Imagineerium* project, this other (quantum) conception, characterised by hybridity and a multicultural environment, is one which teachers have become familiar with and can value. Teachers report admiration for the engaging and complex mix of skill, knowledge and understanding developed simultaneously through the project. The difficulty lies in their reconciliation of an account of *schooling* that can be conceived of within this alternative conception. We conclude by suggesting that this translation can be promoted by the kind of *imagining* and *metaimagining* identified by Steier and Kersting, supported by an iterative process of drawing, bodily actions and discussion between teachers, supported by those for whom the kind of account of STEAM we

are promoting is becoming familiar and valued. Such a focus on imagining, embodiment, drawing, etc. is central to the kind of STEAM practices which have been found effective in *The Imagineerium*, and which is underpinning our new work with teachers to develop such hybrid curricula in schools.

Conclusion

The problem this article set out to consider was in part practical, in the sense that it is grounded in the difficulties we experienced in helping teachers to conceive the curriculum differently. This was the case even though they had recognised the value of a specific hybrid project, *The Imagineerium*. In part it was ideological, in that our overall project sought to overcome the servant status of the arts in STEAM education.

We have argued that teachers (and pupils) tend to conceive of curriculum space-time in subject-specific ways in which one subject occupies one timetable 'slot'. Thus, any attempt to include another subject leads to its servant status. Drawing on Massey and Geertz allows us to set out the issue in a way that leads to practical resolution. It also leads to a greater understanding of the issue and the way forward for STEAM education as a whole.

The foregrounding of the *culture* of subjects, particularly the culture of the arts, as a multicultural frame, and the distinction between *form* and *culture*, opens up the intelligibility of a coherent, rich, educative experience, and the role of hybridity in curriculum planning and delivery. The focus on culture, and explicitly in the ways meaning is established in subject areas, both enables hybridity of cultures and the ascription of hybrid meanings to the forms produced, performed and studied in a specified timetable slot. We recognise that more needs to be done in exploring these hybridised subject cultures, but such specificity is beyond the scope of this article.

What is 'in scope' is the recognition of the different conceptions of curriculum space-time that are possible. In drawing on Steier and Kersting, we identify the kind of process that is required for teachers to shift their conceptualisation from a Newtonian to a quantum conception of such space-time. In doing so we are not simply finding a useful parallel or metaphor between students' understanding of space-time and teachers' understanding of space-time, but rather articulating how subjects can be equally practised and valued. We also thereby claim that the pedagogy required to achieve the shift in conception is the same in both cases.

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NOTES

[1] We use the term 'subjects' rather than disciplines to reflect the more natural language of primary school policy and teachers.

[2] We use the hyphenated term 'space-time' to indicate that we are locating actions and subjects at the same point in space and the same point in time; that is, utilising a common-sense or Newtonian conception of space

and time. Later in the article when referring to relativistic physics we use the unhyphenated 'spacetime' to express the ontological claim of four-dimensionality.

[3] Our purpose here is not to report on the key findings of this project, which are reported elsewhere. Qualitative data from all 4 years of the project indicate a perceived benefit for pupils, by both pupils and their teachers. There is also evidence of the value for teachers in helping them re-evaluate their pedagogies across all subjects. Quantitative evidence has identified a number of positive impacts on pupils' perception of themselves as learners.

[4] The term originated in American corporations, most notably Disney, and refers to those developing engineering solutions in the creative and imaginative industries.

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