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Research Question Cluster Four:

- *To what extent does the study of Design & Technology improve attainment in other subjects, especially English and maths?*
- *How far does Design & Technology within STEM projects help pupils make sense of the maths and science?*
- *What is the relationship between Design & Technology and engineering education?*
- *What does Design & Technology bring to engineering that maths, science and ICT do not?*

Introduction

In light of the bringing together of four questions into a cluster we have identified several issues we think are important. As will be seen the issues are treated to different degrees and are certainly not exclusive. In a study of this scope there are major avenues for research that cannot be explored in the time available. Consequently, a limited literature review has been conducted and there is a degree of speculation presented. Nevertheless, such material is also the considered professional opinion of the authors and is, we believe, capable of expansion and elaboration if necessary.

Inasmuch as the questions are symptomatic of current curriculum politics (with both large and small ‘p/P’) we have given some treatment of the questions as a curriculum commentary. Elsewhere we have introduced some psychological, social and philosophical argument and evidence to address matters raised by the questions.

The cluster of questions re-framed

Implicit in this group of questions is the notion of ‘subject’ and consequent cross-curricular relations. (The immediate context of the questions in the National Curriculum for England [QCDA, 2011a]. Many other curriculum models and possibilities are available in other jurisdictions around the world.) This consideration is raised because it is here that much circularity can occur. D&T’s integrity and its search for curriculum identity is not helped when it is continuously having its nature *challenged, determined* or *expressed* by/through other areas of curriculum activity.

D&T is *challenged* when other subjects ‘lay claim’ to its business. There are those who see technology as applied science, or who see technology and science as having some ‘special relationship’. Some would

argue that the ‘hands-on’ tool-use aspects of materials manipulation to be craft and this, along with design, should be the remit of Arts education. Yet others would see the socio-critical (eg sustainability and ethical aspects of the field) belonging in the field of social sciences.

D&T is also socially challenged when its worth is deemed as being lesser than (say) ‘academic subjects’ or being a ‘practical’ field which, in part, it is but the term ‘practical’ is itself inadequate both in educational discourse in general and in addressing D&T in particular. All education is, in its way, practical. D&T is an integration of many aspects of human endeavour and learning into practical can-do, or capability. This is part of its integrity.

D&T is *determined* ‘by default’ when it is described not by what it is but by *what it is not* in terms of other subjects. Thus there is a double edged sword at work when we say that D&T is not ‘applied science’, nor ICT, nor craft, nor vocational education, nor environmental education as it can interplay with all of these and yet is none in particular. As a holistic enterprise, D&T does not sit well in a world of ‘subjects’ but the problem here lies not with D&T but with a curriculum organisation that is dependent on such divisions.

There is also a danger of D&T being *expressed* not as a subject or field of human enterprise with its own integrity but because of its role (as a ‘lesser’ subject) in servicing other subjects. There is a significant irony at play here. On the one hand, D&T is educationally comprehensive enough to support literacy, numeracy, science, reasoning, sustainability, creativity, and more. Meanwhile, on the other, despite the realisation that D&T is strong in servicing other subjects, those very subjects are more often not servicing D&T with equally respectful vigour. Here matters of both resourcing and status are at play.

Further, beyond the field, there are multiple agencies and organisations all too ready to say what D&T should or should not be. This phenomenon was well documented by Layton (1994) who identified six (for a start) generic groups who would all be stakeholders (he called them ‘actors in this curriculum drama’) in the determination of D&T curriculum. The rollout of players, each with their own agenda, continues with, of late, the RSA returning to the fray (McGimpsey, 2011; Miller, 2011).

Sketches from the National Curriculum

We are drawn by the cluster of questions to explore D&T’s supportive (service) role with other subjects. One exercise is to look at the National Curriculum Subjects’ *Key Concepts* (Key Stage 3 has been selected) and identify which can readily be supported through D&T practice. However, we would argue that two important matters should be borne in mind when conducting this interrogation. First, to what extent are the subjects supporting D&T’s own enhancement – this is a matter of curriculum reciprocation. Second, it can be asked to what extent are some Key Concepts nothing other than universal concepts that can be found in all good teaching and learning, in whatever realm or context – a matter of concept ubiquity.

To illustrate the ground here, in Key Stage 3 ‘Cultural understanding’ is a key concept identified in D&T (QCDA, 2011c), Science (QCDA, 2011h), English (QCDA, 2011d), and Art & Design (QCDA, 2011b); ‘Cultural, ethnic and religious diversity’ is so in History (QCDA, 2011e); while Mathematics (QCDA, 2011g) has a Key Concept sub-set of ‘historical and cultural roots’. Similar scrutiny reveals multiple appearances of ‘creativity’, ‘competence’, two constructions of ‘critical’ and ‘capability’. Might there not be a case for ‘design’ or ‘communication’ too? Appendix One offers a *sample* selection of National Curriculum Subject Key Concepts, those of ‘Creativity’ and ‘Critical evaluation/understanding’ and shows the potential for both reciprocation and for ubiquity.

A situation arose in South Australia where, with the introduction of five ‘Essential Learnings’ (which were to interweave all eight ‘Learning Areas’ – each a cluster loosely based on groups of subjects), it became possible to imagine the curriculum realigning from an organisation based primarily on Balkanised departments and subjects (Hargreaves, 1994) with these Learnings woven through them, to one of Essential Learnings with ‘subjects’ woven through to support the desired learning (Keirl, 2002). Thus, in England, if enough cross-curricular constructs such as literacy, numeracy, cultural understanding, design, creativity and so on were to be foregrounded would this not amount to a rationale for the dissolution of subjects – or at last those (unlike D&T) so narrow in their epistemology as to be indefensible in a 21st Century curriculum? Here, debates that lie beyond the scope of this brief paper begin to open up.

A simple illustration of the organisational issues arising around reciprocity, ubiquity, learnings, and subjects is offered in an extract from Lloyd & Busby (2010). In their work on *communicating* in the professional practice of engineering design, they refer to the skill of:

...using and manipulating language – a strongly social ability.

There are educational implications here. If such a skill is something the experienced design engineers can perform without training, then explicitly nurturing that skill in students with a low level of experience might be worthwhile. (They suggest...) education in rhetoric and aesthetics as important areas of curriculum development in engineering design. It is highly likely that this knowledge could help engineers to become aware of the varying types of reasons, information, and experiences that design decisions are based on, and help dispel the myth that all engineering information is somehow scientifically based. (Lloyd & Busby, 2010:258).

If this were to be brought to the school setting, a case might be made for English lessons to support the work of Design and Technology but the issue of division by subjectification remains. Certainly there are numerous pointers to how D&T learning can be supported by, and interact with, the Key Concepts, Key Processes and associated Explanatory Text sections of the English KS3 Programme of Study (QCDA,

2011d). Further research would show the same for other subjects notably but not exclusively, science and maths too.

The English - Design and Technology rapport as a case for study.

The world as it experienced cannot be well understood through an arbitrarily and historically divided curriculum. Perpetuating past paradigms has led today to a subject-based curriculum yearning for integration. Robinson (2010) builds on a decades-old critique of English (national) education and challenges the continued separation of subjects within the public education paradigm. He notes how, historically, this approach to learning has had a relatively short existence and that a segregated view of knowledge would seem to be ineffective in providing quality educational experiences for today's students – the people who will be living, working, and communicating in a future world for which we hold only partial understanding.

Preparation for future life is currently based on defunct structures, contents of education that are draconian, often binary in nature (academic vs non-academic) and systems which determine that the best way to group children for learning is by using one measurable characteristic such as age. Landry and Bianchini (1995) recognized that the industries of the twenty-first centuries, being those that contribute to communities around the world in the form of employment and social capital, would depend on the generation of knowledge through creative enterprise and innovation of design. They also say that knowledge, enterprise and design will be accompanied by 'rigorous systems of control' (Landry & Bianchini, 1995:12). By continuing to promote a differentiated curriculum that comprises segregated subject areas rather than creating a holistic approach to learning (viz. Bloom, 1956) current education systems are unlikely to prepare students to take their place in dynamic future communities.

The mismatch for students between how they experience the world and how they experience fragmented knowledge demands that subjects cannot stand in isolation from one another. Rich understanding and meaning-making cannot occur unless multiple and integrative approaches are taken towards knowledge and learning (and, implicitly, pedagogy). The Association's Manifesto for Design and Technology Education (DATA:2011) rightly identifies the case for a holistic approach to curriculum design when it suggests that 'D&T provides a natural opportunity for children to put into practice and improve basic skills in English and Maths' (DATA, 2011:15).

As just one area of exploration, what can be said about the relationship between English and D&T? How can these subjects interplay in ways that improve students' skills, knowledge and confidence to play fulfilling roles in their communities? English, as a bastion subject of the public education system is becoming increasingly so because it is heavily targeted (as with Maths, nationally and internationally) for standardised testing. This, in turn, valorises particular pedagogical restrictions as well as resource privileging.

Another curriculum irony has been the rise in the use of critical theory (eg Habermas, 1971) in informing critical pedagogies and critical literacy movements while, at the same time there has been a parallel rise in the instrumentalisation of curriculum. The two are not compatible and opportunities may arise in the near future for new settlements out of the meeting of the two. In advancing alternative pedagogies the New London Group (1996) argued that emergent radical ways of working would require teachers to abandon their technocratic roles and help students to develop new critical strategies to thrive in dynamic work, social and community conditions. They penned the term “multiliteracies” to extend the narrow view of literacy, which was centred on the use of language, to a cognitive, culturally and socially sensitive contextualized focus. This ‘new’ way of viewing the idea of literacy would demand new pedagogical practices that were able to evolve within the cultures of use and, for this review’s purposes, such cultures could be any of a host of D&T-related workplaces, consumer practices or imagined futures.

The current English curriculum has speaking and listening, reading and writing as its three key areas of focus. We can assume that multi-modal methods of addressing these three areas are embedded in practice to represent the cultural and social diversity of the contexts in which it is practiced. In other words, teachers would be engaging with the subject in ways that enabled their students, wherever they may be applying ‘English’, the opportunity to chose contexts through which to develop the required concepts, skills and knowledge – and the cross-curricular would be an obvious avenue. When one considers that most other subjects require the fundamental skills of speaking, listening, reading and writing for students to interact meaningfully with subject material, then the cross-curricula nature of English is undeniable and, ideally, fundamental to learning.

The current Design and Technology curriculum has, as its first Key Concept at Key Stage 3, ‘Designing and making’ where students would gain the ‘understanding that designing and making has aesthetic, environmental, technical, economic, ethical and social dimensions and impacts on the world.’ We also find that students are to develop an ‘understanding that products and systems have an impact on the quality of life.’ These are broad, encompassing concepts that implicitly necessitate students to have the command of effective communication skills in order to demonstrate their attainment. It is through such engagements and investigations that Design and Technology best provides a vehicle for delivering the English curriculum. Even the required study of a Shakespearean play, as part of the required curriculum, would demand the investigations of systems (social relationships, materials) that were in use at the time of their writing and production so as to best understand the genre. English, itself, as a system of communication offers the Design and Technology student a powerful investigative opportunity to explore the development of the language system, how it evolved through use, critique and the development of other (non-digital) communications technologies – those, historically and currently, which were/are enablers of writing, speaking, reading, and listening.

In the Critical Evaluation section of D&T Key Stage 3 Key Concepts students are to ‘analyse existing products and solutions to inform designing and making which includes ‘sharing and negotiating successful practical solutions’. Analysing existing products to inform new design engages analogy in the design process and requires the use of analogical reasoning. Mental model theory suggests that students make relational links when they use analogy and this helps to ‘strengthen the network of related meaning by anchoring similarities of the new mental model to analogous structures within existing mental models’ (Edwards-Leis, 2010:35). Such processes, that help to develop cognitive strategies that are cross-curricula, could also help develop student’s design skills and to teach abstract concepts (Daugherty and Mentzer, 2008).

There are significant opportunities embedded in the realm of suggested content that would engage students in developing the ‘English’, ‘literacy’ or ‘multiliteracy’ skills. Reciprocally, these skills can be used to reflect on solutions where students respond to interrogative questions to ‘explain, justify and evaluate their finished design’ (Winkelmann and Hacker, 2010:305). These authors’ study, which involved students and experts designing an artefact to meet a list of requirements, showed that significant improvements in the quality of the responses were possible by using structured questioning aiming at semantic relations in systems. This question-based reflection (Cottrell, 2003) variously explored: ‘why’ questions provoked search for causes, discernible from used causal conjunctions like ‘because’ or ‘as’; and ‘what’ questions looked for reasoning through responses that engaged responses such as ‘in order to’ and ‘with it’ (Winkelmann and Hacker, 2010, pg. 306).

Significant research is taking place that explains the cognitive processes that students use within Design and Technology contexts (Daugherty and Mentzer, 2008; Edwards-Leis, 2010; Winkelmann and Hacker, 2010). The opportunity for Design and Technology activity to engage students in learning that demonstrably improves their use of English (literacy/multiliteracy) skills can also be explained through two multi-modal, innovative (yet ancient!) pedagogical practices. Digital Storytelling and Podcasting can both harness Design and Technology activity to strengthen cognitive processes with a focus on English (literacy/multiliteracy) skills. (These two approaches are returned to in Research Question Five.)

Although we have had a brief look at, first, the overall curriculum picture that frames the questions at the head of this paper, and, second, the potential of Design and Technology and English to conduct curriculum interplay, we have not ventured in depth into the subsequent questions concerning Engineering, ICT, Maths and Science. However, the research is begging and we record the following (few) points:

- Engineering is not recognised as a National Curriculum subject;
- ICT is recognised as a subject yet can probably be described as ‘un plat du jour’ or, as recently described in a letter to the Guardian, an ‘artificial subject’ (Gardiner, 2011:31);

- ‘Maths’ and ‘Science’ are, like English, curriculum bastions whose unwarranted status is currently further enhanced by OECD agendas on education;
- Subjects or not, these four belong firmly in the positivist realm of epistemology and, in combination (real or perceived): i) form a powerful threat to a balanced curriculum for the 21st Century; ii) are justified on predominantly economic grounds; and, iii) valorise particular pedagogical and assessment methodologies.
- STEM has little educational foundation other than supporting a particularly narrow economic-industrial agenda and being a neat acronym. Searches of STEM activities produce no substantial theoretical educational rationale underpinning nor any consistency in political interpretation of its applications. In STEM Design is invisible. To many STEM conferences (Design and) Technology, the school subject is alien.
- D&T brings to all four of these just what it brings to History; Geography; Personal, Social, Health and Economic Education; English; Citizenship; Art and Design; and other subjects – rich language, conceptual connectivity, creativity, meaning-making, integration and holism.

The above points are made to signal both the need for strong, well-researched (theorised) educational argument pro-D&T and to caution against simplified or simplistic explanations of what curriculum is or whose interests are being served by public education.

Concluding comments

We live in a stimulating world that is best explored through all our senses. In whatever way students learn – by witnessing phenomena or by creating them – their learning is deficient if it is fragmented and unrelated. Meaning-making comes through the creating of an ever-expanding whole that constitutes experience. Bloom (1956) was right when he said that holistic approaches to learning will best provide the opportunity to enrich education through analysing, evaluating and creating. Indeed the arguments that can be interpreted in favour of D&T as holistic and student-centred experience go back a century to Dewey (eg Dewey, 1902; 1916). Design and Technology, of all the English National Curriculum subjects, is arguably best placed to provide students with opportunities to engage in holistic learning that enables them to develop and strengthen concepts, skills and knowledge from diverse ‘subject’ areas – or, better, to integrate their understandings of the world in personally meaningful ways. Investing in Design and Technology *throughout* all students’ formal education lives is essential for providing rich and authentic learning opportunities.

We believe that, ultimately, the answers to this cluster of questions (and there are other similar ones that could be included in such a cluster) lie in the matter of D&T’s integrity. Thus, the following can be borne in mind:

- D&T is a powerful integrator – of experiences, of learning and of subjects;

- Meaning-making happens for students as they engage in this integration through design activity where proposals and ideas are realistically tested, modified or rejected. Such activity draws upon, and valorises, ‘other’ subjects’ content;
- D&T’s own integrity is still underdeveloped and is under-articulated. The Manifesto is a great step forward but the marginalisation of D&T by other interests, agendas and trends will remain a challenge;
- In such circumstances there are matters for curriculum resistance and advocacy to consider regarding the challenges to, determination of, and expression of D&T *by others*. Unlike, ICT, D&T is not an artificial subject created in recognition of a particular technological development. D&T has a worthy pedigree (perhaps now is an inappropriate time to celebrate its roots and its proven capacity to adapt);
- Matters relating to STEM are not straightforward – a thoroughly argued (theorised and researched) position paper is warranted;
- From a devil’s advocacy position of ‘know thine enemy’, a thoroughly argued (theorised and researched) case for the dissolution of the subject ‘D&T’ (in the current climate of Balkanisation and instrumentalism) might be possible;
- If the ‘working context’ is taken to be the current National Curriculum then the matters of *curriculum reciprocity* and *concept ubiquity* might be explored in depth...;
- ...However, a cautionary note is needed as the National Curriculum is a poor mimic of those of (say) South Australia (Essential Learnings) and New Zealand (Key Competencies) and their respective Learning Area Frameworks;
- This brief study is limited in many ways but we note our National Curriculum limitation to Key Stage 3; and, finally;
- Wider education debates and contestations are afoot in many arenas (academia, media, politics, industry, etc) and it is possible to conceive of an optimistic outcome for D&T whereby a new settlement emerges from current tensions. As the Association appreciates, such an outcome calls for engagements on many fronts (not just those invited in this cluster of questions) but, ironically, to return to a much-used term in this paper, an integrated approach is needed – one which is an advancement of D&T’s very special integrity.

Appendix One: Sample selection of National Curriculum Subject Key Concepts - comparisons of 'Creativity' and 'Critical evaluation/understanding'.

Key Concept	NC Subject	Concept detail supportable by D&T
Creativity	Design & Technology	1.3a Making links between principles of good design, existing solutions and technological knowledge to develop innovative products and processes 1.3b Reinterpreting and applying learning in new design contexts and communicating ideas in new or unexpected ways 1.3c Exploring and experimenting with ideas, materials, technologies and techniques
	Art & Design	1.1a Producing imaginative images, artefacts and other outcomes that are both original and of value 1.1b Exploring and experimenting with ideas, materials, tools and techniques 1.1c Taking risks and learning from mistakes
	English	1.2d Using creative approaches to answering questions, solving problems and developing ideas
	Math's	1.2c Posing questions and developing convincing arguments
Critical evaluation	Design & Technology	1.4a Analysing existing products and solutions to inform designing and making 1.4b Evaluating the needs of users and the context in which products are used to inform designing and making 1.4c Exploring the impact of ideas, design decisions and technological advances and how these provide opportunities for new design solutions
	ICT	1.5a Recognising that information must not be taken at face value, but must be analysed and evaluated to take account of its purpose, author, currency and context 1.5b Reviewing and reflecting critically on what they and others produce using ICT
Critical understanding	Art & Design	1.4a Exploring visual, tactile and other sensory qualities of their own and others' work 1.4b Engaging with ideas, images and artefacts, and identifying how values and meanings are conveyed 1.4c Developing their own views and expressing reasoned judgements 1.4d Analysing and reflecting on work from diverse contexts
	English	1.4a Engaging with ideas and texts, understanding and responding to the main issue 1.4b Assessing the validity and significance of information and ideas from different sources 1.4c Exploring others' ideas and developing their own 1.4d Analysing and evaluating spoken and written language to appreciate how meaning is shaped (NOTE: when 'texts' and 'language' are seen as <i>technologies</i> the parallels are evident)
	Math's	1.4a Knowing that mathematics is essentially abstract and can be used to model, interpret or represent situations (NOTE: here mathematics can be seen as a <i>technology</i>) 1.4b Recognising the limitations and scope of a model or representation

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