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Full Steam Ahead

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As we approach the second decade of the 21st century, a true technology era, what is essential for the learner, regardless of age, is how they can leverage technology to access them to subject matter while engaging and activating higher order thinking skills. The pedagogical geometry is no longer vertical, it is horizontal. Rather than seeing the Arts disciplines and the Science, Technology, Engineering and Mathematics realm as disparate, as discreet elements on a vertical line, we need to see them as entwined, as a transdisciplinary or horizontal approach to access all types of design, make, appraise, thinking: to problem solve. We are all learners and teachers in a world where we must anticipate the product to generate the solution, we have to learn to use a meta-map to think our way through the hyper-scale infrastructure accessible to us - do we know how? This chapter sets the scene for the current debate re the place of the Arts in the horizontal agenda and proposes a STEAM focus in education into the 2020's.



What is the STEM/STEAM debate?

Since the end of the 20th century advocacy for adding an engineering component to a new breed of comprehensive Science education that interfaces with technology and Math has found a voice (Angier, 2010; Bequette & Bequette, 2012; Boy, 2013; Carroll, 2014; McAuliffe, 2016). Science, Technology, Engineering and Mathematics (STEM), in this article, is a paradigm where experiments are conducted to address problems in those fields that can be better tested using all of those fields, through the scientific method. The scientific method is an inquiry process used to systematically study, investigate and to provide explanation for observed phenomenon in the natural world. This method is used by STEM professionals to answer questions they have about important world problems for the future and usually includes carefully orchestrating a situation that allows them to observe, measure and test their ideas.

Firstly, let's be sure about what is meant by preparing for 'the future'? In a dictionary sense the word 'future' is defined as that which is about to happen or be or become; relating to a time that is to come. According to Slaughter (1996) the future "is a general category, like the past and the present. It is a dimension of human existence; a broad generality and an active principle in our everyday lives" (1996, p.39). Bell (1999) argues the future is something that people can shape and design through their own actions. This parameter is characterized by the role played by expectations and anticipations, where actions, choices and decisions are made in relation to the here and now (Nowotny et al., 2002). In this parameter, the present is linked to the future through concepts such as strategic planning, economic and business activity forecasts and scenario planning – processes which now characterize the operations of business, industry and government (Nowotny et al., 2002; Schwartz, 1991).

By using such techniques, the future can now be experienced as an 'extended present' in which correct decisions and actions can be taken in the expectations that the future can be shaped. Thus contemporary organisations are concerned with 'visioning' and the identification of trends and mega-trends (Nowotny, et al. 2002). Teaching and education then are examples of a futures strategy, as they seek to shape future society by preparing today's youth for a world that does not yet exist (Hargreaves, 1998). Enterprise by its very definition necessitates bold undertaking. The significance of the STEAM agenda is the exploration of opportunities to influence the direction of the future, to identify how to respond and cope with the future as it unfolds (Slaughter, 1999). Exploring the future enables an evaluation of plans or the definition of the means by which those plans can be implemented and thus identification of the likely consequences or outcomes. This Futures perspective requires that humanity shape and design the way forward, that we have some control in how events unfold to create our future – a pedagogical paradigm that will be referred to throughout this article as prototyping.

The 20th century was based on local linear engineering of complicated systems states Boy (2013). We made cars, airplanes and chemical plants for example. The 21st century has opened a new basis for holistic non-linear design of complex systems, such as the Internet and air traffic management. Interconnectivity, communication and interaction are major attributes of our evolving society. Boy



(2013) posits that, systems need to be investigated and tested as wholes, a systems analysis which requires a cross-disciplinary or horizontal approach but also new conceptual principles and tools to enable collaborative work using higher order thinking to innovate and solve emerging problems. Consequently, schools cannot continue to only teach isolated disciplines based on a defined body of related content (McAuliffe, 2016; Lynch & Smith, 2016).

The STEM, *Science, Technology, Engineering, and Mathematics* versus STEAM debate is concerned with whether it is necessary to integrate the Arts in order to promote creativity together with rationalization, to access curriculum and utilise pedagogies horizontally, rather than vertically. The author would propose, as do others (McAuliffe, 2016; Boy, 2013) that a move (back) to STEAM (with an "A" for *Arts*) is a move back to the appreciation of the aesthetic criteria in design. Consider the obligation of engineering and architecture to civic beauty and the use of the principles of proportion and scale. These principles have never been ignored in bridge design and town planning and these notions of creativity and aesthetics shouldn't be discounted from the STEM rhetoric merely because they have not been clearly articulated as essential elements previously – now is the time to recognize the place of the ARTS in STEM and keep it on the agenda.

The concept of STEAM is not new as established previously, Leonardo Da Vinci, the epitome of the Renaissance man (circa 1300 -1600) is also the quintessential example of a STEAM practitioner. Just as Da Vinci himself was a controversial man, much sought after but much maligned - was he an artist or an engineer? – the place of Arts in the STEM agenda is a contentious one. Having established that the real construct behind the STEM/STEAM debate is in fact not new – we turn to the next question: do the Arts disciplines have recognition as rigorous teaching and learning environments, as worthwhile career pursuits? The culture shift necessary for the inclusion of the Arts will be a constant undercurrent in the 'putting the 'A' in STEM = STEAM' debate.

This concept shift also emphasizes the importance of innovation and prototyping in bringing research and design into action. STEAM based design can contribute to not only improving education technologies, systems, design execution and practices, but also as a discipline, offers an integrated approach to learning by doing. Learning by doing is about expressing and critiquing, exploring possible futures, and understanding complex systems as we collaboratively problem solve. STEAM teaching and learning environments facilitate learning by doing and enhance learning thinking (Boy, 2013, Lynch et al, 2016).

Collaboration, in this context at a trans-disciplinary subject level, is the future: it is NOW and STEAM is a now methodology. However, Bequette & Bequette, (2012) warn that the artistic or creative process becoming an essential element of STEAM education could potentially either and or both be

- a. an opportunity for greater prominence for art education, better Arts and STEM learning and heightened student engagement
- b. weaken each discipline and confuse the boundaries between different approaches



Whether the 'colours' of each discipline within the STEAM approach fade will depend both on the nature of the tasks that learners collaborate to problem solve and the pedagogies used to plan for teaching and learning.

How can student engagement, learning, and interest be fostered by more integrated art and engineering teaching?

The OECD (2000) defines the contemporary learning economy as one where the success of individuals, regions and countries will reflect, more than anything else, their ability to learn. The acceleration of change reflects the rapid diffusion of information technology, the widening of the global marketplace and the re-regulation of and diminished stability in markets (OECD, 2005). The unique characteristics of knowledge and the dynamics of the knowledge economy mean that a cultural change is required from thinking in terms of production to thinking in terms of innovation (DEST, 2002).

Lynch, Smith and Howarth (2016) state that across the globe governments seek to improve their education systems because a Knowledge Economy requires all of its citizens to be highly educated and prepared for a world based on technology, innovation and ongoing exponential change. We live in a knowledge economy, an information society, the content is at our fingertips as long as we are ICT literate, have been shown how to discern and reference a reputable and valid source, have been empowered with the thinking skills (Doe, 2013; 2014; 2015) and a device and strong connectivity we can solve future problems using a STEAM approach. The predilection of the 21st Century learner, whether we call them gen C, gen Y or gen Z, the net generation, millennials, digital natives, the online generation or the gamer generation is unlikely to be a lecture! Today's learners have multi-modal learning abilities and an emerging range of blended learning opportunities at their disposal to solve problems, so how does this impact on teaching?

How does STEAM impact on Teaching?

It follows that professional learning for teachers needs to enhance their practice through a futures orientation in order to address contemporary classroom learner needs, (Doe, 2013; 2014; 2015; Lynch & Smith, 2002; Ingvarson et al., 2004) however neither do we expect digital tools to provide pedagogical solution in and of themselves. Moving everything online will not build capacity if the pedagogy remains subject-centered, expert-driven and teacher-led, then ICT's will not have been embedded and nothing will change. We can't redesign our learning spaces overnight but we can change how we use them so that the work in inquiry-based, project oriented, negotiated in collaboration to set criteria. Einstein said *for knowledge is limited to all we now know and understand while imagination embraces the entire world and all there will ever be to know and understand.*

If you take Einstein to be referring to the creative industries, the Arts are the perfect complement and supplement to the STEM agenda. The question here is: what do the Arts add to the picture that make STEAM more 'bang for buck'? The real traction is achieved in setting up project scopes that allow learners to innovate for the solutions created through engagement with available technologies, to access data and work towards identified deficits and celebrate successes. If hyper-scale infrastructure is going to become an enabler, how well are we growing teacher capabilities to access themselves and their learners to it? Further how well are enhancing the practice of our teachers to provide quality teaching and learning opportunities that explore the infrastructure through experimentation and innovation in a true STEAM learning environment?



To enhance 21st Century pedagogy for a STEAM agenda, we must focus on research-based strategies that have an effective size of $> .4$ (Hattie, 2012), strategies that guarantee impact evidence in learner outcomes. It is the teaching of the skills, the way that teachers, trainers, employers, mentors and academics blend the learning through combining traditional 'bricks and mortar' approaches with on-line platforms and technologies that form a STEAM approach that will prepare 21st Century graduates, skilled to meet marketplace needs. Connectivity as a reality negates the need to worry about accessing information and knowledge, it is now about concentrating on meaning in context (Boy, 2013), creativity and design thinking need to be considered equally with analysis and reasoning in a STEAM agenda.

Global, National and State incentives for STEAM and an innovation agenda are hot topics currently. Microsoft Queensland are staging a professional learning event titled *Full STEAM Ahead* which is about bringing a STEAM learning paradigm to schools during a period of transition in Education that is both exciting for some and very daunting for others. Matthew Jorgensen, Teacher Ambassador, Education, Microsoft Australia states 'there is a creative transformation happening, and both major political parties are looking to invest heavily in our schools, teachers and students in order to develop this country into an 'innovation nation'.

Collaborative communities (transdisciplinary) support learning thinking and enhance critical thinking through use of technologies to combine abstractions and concrete visual representations of real world objects and phenomena (Boy, 2014). Boy (2014) states that since we now have the means to make many abstractions more concrete, visually and or physically meaningful, instead of dividing disciplines, we need to combine them through problem solving and action – we cannot be either artist or engineer any longer, we must be both. If we recognize the need to combine humanities and technologies while maintaining specialized knowledge, then we must quality assure for impact evidence that demonstrates real meaningful collaboration as the foundation of transformative 21st Century education (Carroll, 2014). A transdisciplinary STEAM approach to design thinking process puts the ownership of the problem in the learner's hand – they have to reframe problems as opportunities with multiple viable solutions.

If we want to prepare teachers with the pedagogical mastery (Pink, 2011) to facilitate a STEAM agenda, we need our people to take risks with the hyper-scale infrastructure at their fingertips. This is about giving our teachers permission to fail and support to succeed through action learning that puts the faces on the data (Sharratt, 2012). If our teaching workforce are both data-driven and creative (Robinson, 2006) they will be positioned to maximise the use of emerging and existing digital technologies. To bridge the theory-practice divide (Boy, 2013; Doe, 2013; 2014; 2015) we have to collaboratively reach the tipping point and put STEAM theory into action through professional learning that changes practice (Doe, 2013; 2014; 2015) through learning thinking, learning by doing: teacher professional learning that teaches STEAM by modelling STEAM thinking.



What is a Prototyping Mindset?

For STEAM thinking to leverage access to the curriculum, it is critical (Carroll, 2014) to focus on creating learning environments that teach the fundamental mindsets and processes of design thinking and are entwined with content learning. Carroll's (2014) studies have shown that to become design thinkers it is critical to develop a methodology that demonstrates a

- a. prototype mindset
- b. creative confidence

Carroll's 2 part methodology above emphasizes the need for teachers and learners to have confidence in their creative ability. This prototyping mindset between student and teacher can be activated through learning design thinking. An enhanced STEAM learning experience occurs, where the learners actually push the boundaries of learning by learning through doing to figure out a response, by practicing a prototyping mindset – where solutions are drafted and redrafted to project specifications/criteria. A prototype mindset to problem solving is an indicator of 21st Century thinking and in particular the demonstration of resourcefulness and resilience. Not everyone has to win a prize, failure is part of the mindset of learning through doing – the important element is the thinking, the process of drafting, making and revising to meet client/brief needs. A prototype mindset is characterized by bias toward action – trying something and learning what didn't work and then spending a long time analysing, talking and finally recreating (Carroll, 2014).

Bequette & Bequette (2012) also place emphasis on prototyping, stating that the Arts are a way of knowing in today's educational climate – they quote the field of engineering which they define as concerned with finding answers to problems and seeking visual solutions using the design process. A prototype mind-set and being in the moment is best evidenced by such examples as a pre-planned 'STEM – A' scenario such as traditional automotive engineering. We can have all the high end technology that makes a new car as good as it can get in terms of economy, safety and functionality for the user but if we don't add the 'A' for aesthetic design then the new car won't package as a product that is hot and stylish and ultimately who is going to buy an ugly car in today's marketplace?

Bequette & Bequette (2012) highlight prototype construction as essential to the design process. They argue that interdisciplinary work in the Arts and sciences can lead to curricular components that combine aesthetic and analytical modes of thinking to the betterment of both science and art (Fitzimmons, 2011). The argument presented here is that creativity and innovation cannot be treated separately from STEM and arts should be an integrating part of a, no longer novel, approach called STEAM (Boy, 2013). This is not, according to Boy (2013) about integrated curriculum but about integrating disciplines, using horizontal pedagogies, to access all capabilities; to problem solve which means managing the growing complexity of socio-technical learning in a digital society.

What contribution can the Arts bring to the STEM table?

Invention is a signature complex reasoning for the Arts and hence it's place on the STEM agenda (Carroll, 2014). In particular, the contribution that design thinking is bringing to the global community is the ability to think creatively and abstractly, an intelligent behavior that brings people to a more refined solution in many contexts. The Arts cannot be ignored in



the conceptualisation of business – as shown in the fields of advertising and social media. All we need do to validate the place of the Arts in STEM is to consider why facebook is so popular, what made it so big so quickly? The answer is that its design was an innovative, human-centered response to defining and solving a complex problem in terms of social networking that necessitated a STEAM solution. The finding here is that we need to teach as many people as we can to use both sides of their brain for every problem they have to solve, so that every decision in their lives, they consider creative as well as analytical solutions.

Are our learners children prepared to think and focus for success in 21st Century life?

Ultimately the STEAM agenda is about dealing with how technology is changing the way our children think and focus. The next question this paper addresses then is: Do they have the capacity to reflect, reason, and draw conclusions based on experience, knowledge, and insight? These capacities are what make us human and have enabled us to communicate, create, build, advance, and become civilized. Thinking encompasses so many aspects of who we are and what we do, from observing, learning, remembering, questioning, and judging to innovating, arguing, deciding, and acting. There is also little doubt that all of the new technologies, led by the Internet, are shaping the way we think in ways obvious and subtle, deliberate and unintentional, and advantageous and detrimental. The uncertain reality is that, with this new technological frontier in its infancy and developments emerging at a rapid pace, we have neither the benefit of historical hindsight nor the time to ponder or examine the value and cost of these advancements in terms of how it influences our children's ability to think (Boy, 2013).

There is, however, a growing body of research that technology can be both beneficial and harmful to different ways in which children think. Moreover, this influence isn't just affecting children on the surface of their thinking. Rather, because their brains are still developing and malleable, frequent exposure by so-called digital natives to technology is actually wiring the brain in ways very different than in previous generations. What is clear is that, as with advances throughout history, the technology that is available determines how our brains develop. The emergence of reading encouraged our brains to be focused and imaginative. In contrast, the rise of the Internet is strengthening our ability to scan information rapidly and efficiently (Marin, 2014). Kim Martin (2014) further claims that schools have reached a point of digital technology integration which means educators no longer have an excuse for not supporting individual learners with the right tools to enable them to be creating and contributing to their learning community. Her focus is on accessing educators to the benefits of free, out of the box options that provide learners with greater agency independence and access in their learning. She shares how digital technologies can help create a "least restrictive environment," not only for students with disabilities, but for everyone else as well. In a STEAM world, by her definition, leaders of a digital learning community will need to ensure that all members of that community have appropriate opportunities to achieve worthwhile contemporary and personalised learning outcomes. Linking an inclusive pedagogy to their technology choices is imperative to the STEAM agenda and the STEAM agenda is the platform for 21st Century learning.



Schapiro (2015) suggests that we change the conversation about Education and technology. She claims that there has been a lot of discussion among policymakers and the media recently regarding the pitfalls of using technology in the classroom. Many of these conversations are worthwhile – it's important to be sceptical when spending scarce dollars for public education. The problem is that this debate often centres around the wrong question: Does technology belong in the classroom? If we keep asking this question, we won't make any progress (Schapiro, 2015; Lynch et al, 2016). We know that technology belongs in the classroom. Technology is a tool that helps us develop and apply skills we all value – curiosity, problem-solving, persistence, collaboration, information literacy. So why do we talk so much about devices and software? Maybe, proposes Schapiro (2015) because it's easier. Technology is tangible: you can see it, touch it, and interact with it. You can't see curiosity or persistence. So when technology “failures” occur in our schools, it's easy to blame what's right in front of us.

Impact on Schools and Teaching

Finally, then the importance of investigating technology as a potential roadblock, a current reality for much of the current teacher workforce, in a STEAM agenda is paramount. Furnham (2016) states that integrating technology is different to simply using technology. Training for teachers must enhance pedagogical practice through professional learning that uses such Instructional Models as Doe's (2013) ST2P (Make Space, Take Time, Find Place and Adjust Pace) so that today's teacher can leverage the curriculum using available digital tools. When our teachers can think naturally in a digital world, where there is no distinction between Digital Natives and Digital Immigrants the platform for STEAM learning and thinking will have been created. In terms of change fatigue and change management, Knoster (1991) identifies that a lack of resources = anxiety and a lack of skills = frustration. We need to empower our teachers with the skills to use the available digital technologies better than their learners.

Schools which promote an Information Communication Technologies (ICT) vision such as *Our teaching and learning drives the use of technologies in the classroom where we engage students in a rich learning environment that draws upon an international perspective. As a school community we value the safe and ethical use of technologies* are on the pathway to leverage digital technologies for a STEAM project based working environment. In these schools, a whole school commitment to the continual improvement of educational practices through the support of digital technologies is the focus. The author would propose that the above school ICT vision has been actioned through the Instructional Leadership Model, ST2P (Doe, 2013; 2014; 2015) to enhance the use of blended learning initiatives. Online teaching techniques are being applied both inside and outside the classroom, to access students to the content but the Blended Learning Project itself is also driving change in how teachers are delivering course work –effectively leveraging technology for greater student engagement and success.

Carroll (2014) states that design thinking skills create a space for students where they can develop agency, confidence, and identity as change agents as they respond as innovators to the interdisciplinary nature of design challenges and practice metacognition through social learning. Bruce (2010) adds to the debate with his claim that Arts education has many benefits of cultural value that are not easily measured – creativity, aesthetic sensibilities and appreciation, higher spatial reasoning skills, sensory awareness to name a few. In his search for the purpose of school, Ted



Dintersmith (2015), a highly successful venture capitalist and father of two, is devoting most of his time, energy and part of his personal fortune to education-related initiatives that call for a radical remaking of what and how students learn. He organized, funded and produced the documentary “Most Likely To Succeed,” which premiered at the Sundance Film Festival in January 2015.

Dintersmith’s (2015) general thesis is that what we do in schools - especially in the early years - doesn’t work for a large proportion of the school aged cohort and there is ample evidence globally to support that the ‘system’ is slipping backwards (OECD, 2000; 2002; 2005).

Dintersmith’s claim, and it’s a familiar one, is that today’s schools are failing to produce graduates who are creative, in tune with 21st C conditions, and vocation-ready. Given those conditions, he offers the stock standard solutions of individuality, problem-solving, group activities, teachers as guides and so on. His solution to Education’s woes is a theory of self-directed learning rather than a theory of teaching. He gives priority to the internal cognitive, linguistic, affective, and motivational mechanisms of the child, in our case, the learner. He promotes a STEAM agenda which will foster both self-directed learning and life-long learning.

So if we agree that schooling in the 21st Century needs to be reconceptualised, we must also acknowledge that the first steps in a new direction can be the hardest to take. This paper has presented a need for the Arts in STEM to provide a platform for learning that seeds innovation through the promotion of higher order thinking skills such as risk-taking and prototyping. A focus on innovation, creativity, critical thinking problem solving, communication and collaboration is essential to prepare students for the future (Carroll 2014). A STEAM agenda will assist in transforming education to benefit new millennium learners and help them better integrate our constantly evolving socio-technical society (Boy 2013).

If we accept that we need to teach learning thinking through learning by doing in project-based tasks then we have accepted that knowledge is useful only when applied to real world contexts. Learning by doing is about cultivating adaptive cognitive functions that make knowledge vivid, useful and useable. We will now need to interrogate current case-studies to find the evidence that design thinking provides this robust scaffold for divergent problem solving, that STEAM engenders a sense of creative confidence that is both resilient and highly optimistic.

Full STEAM Ahead

When the arts are seen as an end goal, not just an entryway to presumably more important STEM topics, thoughtfully developed STEAM curricula can truly engage sustained cross-disciplinary learning (Bequette & Bequette, 2012). To facilitate STEAM delivery we must concentrate on professional learning for our teachers that enhances their pedagogical capacity to encourage students to be curious, experiment, and take risks – key dispositions that are engendered by artistic minds. When STEM teachers use the language of functional design, and offer examples of problem-based lessons, extending an invitation to collaborate around project-based tasks using learning thinking they are in fact, working from a STEAM paradigm. Big data and hyper-scale



infrastructure are driving us to a tipping point, to turn research into action, the urgency is no longer if we use the technology but how we use it. Blended learning and STEAM target today's teachers with defining and developing tomorrow's pedagogies. Now to the next challenge, to equip teachers with evidence-based skills to teach to these new ways of thinking, to enhance pedagogical practice. For decades we've been saying that technology will improve student outcomes, so where's the evidence for that? This is where my research is headed:

- Investigating, Coaching, Mentoring and Feedback to analyse teacher practice with digital technologies to leverage learning
- Gathering impact evidence that demonstrates whether teaching teachers Blended Learning using Blended Learning platforms (e.g. Flipped Classroom) enhances pedagogical practice against measurable standards?

Arts is unthinkable without risk and self-sacrifice and hence it has, I believe, a rightful place in the push for 'Full STEAM Ahead'. It's when teachers learn and leaders acknowledge that, for example, the tool, 'one note' is not word, it's a big piece of butcher's paper that encourages innovation and experimentation, that we put the A in STEAM.

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