Why is a STEAM curriculum perspective crucial to the 21st century?

Professor Peter Charles Taylor
Murdoch University, Western Australia

Peter Charles Taylor is Professor of STEAM Education and Director of the Transformative Education Research Centre (TERC) in the School of Education at Murdoch University. One of his main research interests is the development of socially responsible and culturally contextualised science and mathematics education.

Abstract

Well-recognised as a powerful driver of national economic growth, STEM lies at the heart of calls worldwide for educational reform. In Australia, Chief Scientists are calling for STEM education to better engage students on STEM-related career pathways. In the US, STEM educators are being urged to produce graduates with creative and innovative abilities required of an increasingly high-tech workforce. However, an equally important challenge for STEM education is to prepare young people with general capabilities for active participation in community and professional forums for addressing ethical issues associated with the global impact of science and technology. Education for sustainable development remains a pressing priority. Thus, STEM educators are being challenged to design curricula and pedagogies to develop students' disciplinary knowledge and skills, as well as their abilities as critical consumers, creative and ethically astute citizens, innovative designers, good communicators and collaborative decision-makers. There is an international wellspring of educators endeavouring to meet this challenge by combining STEM and the arts to produce a multi-literate citizenry and workforce for the 21st century. In this presentation I will outline how two secondary schools in Western Australia are developing interdisciplinary STEAM curricula.

In this paper I outline reasons why integrating the arts with science, technology, engineering and mathematics is not just another curriculum fad but an important response to the pressing need to prepare young people with higher-order abilities to deal positively and productively with 21st century global challenges (crises) that are impacting the economy, the natural environment and our diverse cultural heritage.

Australian Curriculum: Science

My starting point is close to home for teachers of science. The Australian Science Curriculum provides an exciting futures perspective on preparing young people with not just disciplinary knowledge and skills, but also essential higher-order abilities for working and living in a rapidly globalising world that is experiencing unprecedented development and disruption.

The Australian Science Curriculum is impressively multi-dimensional. As expected, it directs teachers to engage students in developing a range of important scientific concepts and inquiry skills. It then adds the dimension of *science as a human endeavour*, which opens the door to understanding the nature and limitations of science and to considering the cost to the planet and to humanity of unintended side-effects of science and technology. Although this is a significant advance, it is the next two dimensions of the broader Australian Curriculum that fully open the door to a radically expanded scope for science education to address pressing global issues.

The Australian Curriculum has been designed with a higher purpose in mind. Two overarching dimensions – *general capabilities* and *cross-curriculum priorities* – spur teachers to develop their students as global citizens capable of not only adapting to a rapidly changing world, but also to participating actively in shaping it for the better. Importantly, this includes consideration of the many competing (values-laden) perspectives on what 'better' might mean and how to work towards unity in diversity.

The general capabilities focus on developing a suite of higher-order abilities – *critical and creative thinking*, *personal and social capabilities*, *ethical understanding* and *intercultural understanding* – aimed at preparing future citizens 'to contribute to the creation of a more productive, sustainable and just society' (ACARA, 2016). The cross-curriculum priorities – *sustainability*, *Aboriginal and Torres Strait Islander histories and cultures*, *Asia and Australia's engagement in Asia* – provide compelling contexts for students to understand the worldviews of culturally different others and develop a moral conscience about the impact of their planetary footprint. It is intended that teachers of all learning areas, including science, will build these new curriculum dimensions into their teaching programs.

But the prospect of designing teaching and learning activities to develop students' higher-order abilities can be daunting for science teachers. Understandably, many are likely to focus primarily on teaching the 'tried and true' dimensions of science knowledge and inquiry, perhaps with a modicum of science as a human endeavour added to improve student engagement. This standpoint is reinforced by assessment systems that privilege the science understandings and inquiry skills dimensions of the curriculum, especially for Years 11 and 12.

To these teachers I want to emphasise the importance of embracing the new curriculum dimensions. The importance of doing so arises from two significant drivers: economic and sustainability imperatives.

The technology workforce of the future

Given the rapid emergence of digital technologies, artificial intelligence, DNA mapping, robotics, nanotechnology, 3D printing, biotechnology and the 'internet of things', business and industry leaders are calling for graduates with *liquid skills* that enable them to adapt to a fluid working landscape throughout their lives; to prepare for jobs that currently do not exist, but that will be essential to the nation's economic wellbeing.

Liquid skills include the ability to work with others, verbal communication, creative and critical thinking, active listening and active learning, and a disposition towards lifelong learning. These capabilities are deemed to be more important than high academic achievement for IT workers in the 'fourth industrial revolution' (Infosys, 2016).

Recent national reports on future-proofing Australia's high-tech, digital workforce call for STEM graduates with creative and innovative abilities (Australian Government, 2015; PricewaterhouseCoopers, 2015). Australia's Chief Scientist has called for educational reforms to better engage students in STEM-related career pathways (Office of the Chief Scientist, 2013).

Education for sustainable development

We are now experiencing an unparalleled period in the history of the Earth, an epoch in which we have wrested control over Nature: the *Anthropocene* (Crutzen & Stoermer, 2000). This era has its genesis in the industrial revolution and is characterised by our use of fossil fuels and development of powerful technologies. Alarmingly, our technological superpowers are dangerously altering the natural systems of the planet, including the climate, oceans and soils, resulting in fundamental changes to biological and geological systems. The impact of the Western modern human footprint has become so profound that, for the first time in history, natural ecosystems are at the mercy of human systems.

In the public mind, the clearest evidence of our detrimental impact on the planet is climate change (National Research Council, 2011; IPCC, 2014). Another major impact, one that is not so well embedded in public consciousness (unless one is a regular watcher of NITV), is loss of linguistic, cultural and biological diversity, which together are framed as *biocultural* *diversity*. The importance of the intimate interrelationship between language, culture and the environment has been documented by UNESCO, the World Wide Fund for Nature and Terralingua (Skutnabb-Kanga, Maffi & Harmon, 2003):

> In the language of ecology, the strongest ecosystems are those that are the most diverse. That is, diversity is directly related to stability; variety is important for long-term survival. Our success on this planet has been due to an ability to adapt to different kinds of environment over thousands of years (atmospheric as well as cultural). Such ability is born out of diversity. Thus language and cultural diversity maximises chances of human success and adaptability. [p. 10]

Because we have failed to resolve human-induced global crises during the *United Nations Decade of Education for Sustainable Development 2005–2014*, the UN has established the *2030 Agenda for Sustainable Development* (2015), with 17 Sustainable Development Goals. Goal 4 is Education, which is to promote the wellbeing of self, family, community, nation, and humanity at large, as well as the planet's living systems and other life forms. In setting out the following principles of education for sustainable development, UNESCO (2006) recognises that sustainable development is an ethical challenge as well as a scientific concept. Education for sustainable development (ESD):

- is based on the principles and values that underlie sustainable development
- deals with the wellbeing of all four dimensions of sustainability – environment, society, culture and economy
- uses a variety of pedagogical techniques that promote participatory learning and higher-order thinking skills
- promotes lifelong learning
- is locally relevant and culturally appropriate
- is based on local needs, perceptions and conditions, but acknowledges that fulfilling local needs often has international effects and consequences
- engages formal, non-formal and informal education
- accommodates the evolving nature of the concept of sustainability
- addresses content, taking into account context, global issues and local priorities
- builds civil capacity for community-based decision-making, social tolerance, environmental stewardship, an adaptable workforce, and a good quality of life
- is interdisciplinary. No single discipline can claim ESD for itself; all disciplines can contribute to ESD.

In responding to these principles, a 21st century science education for sustainable development (of the economy, the environment and the social-cultural world) would incorporate values education, citizenship education and global issues, and embrace interdisciplinarity. It is clear that, in addition to developing students' science knowledge and inquiry skills, a socially responsible science education needs to contribute to preparing students as future citizens by developing their higher-order abilities, as required by the Australian Curriculum's general capabilities and cross-curriculum priorities.

STEAM curricula

STEM education has become a nationwide focus of innovation and entrepreneurial funding, as witnessed by industry-sponsored initiatives such as the 21st Century Minds (21CM) Accelerator Program, which aims to prepare children with '21st century skills' for the jobs of the future, including the ability 'to think smart and creatively, solve problems, persist and take risks, have strong digital skills and know how to collaborate effectively' (PricewaterhouseCoopers, 2016).

On the other hand, in the nation's schools, especially at the secondary level, the STEM learning areas are relatively bereft of curriculum resources for teachers to foster students' innovative and creative abilities, despite the requirement to address the Australian Curriculum's general capabilities.

Deloitte's (2015) report on the IT worker of the future argues that creativity is a key priority and that STEM educators need to embrace the arts in order to foster students' creative design and performance, using various media:

> IT leaders should add an 'A' for fine arts to the science, technology, engineering, and math charter – STEAM, not STEM. Designing engaging solutions requires creative talent; creativity is also critical in ideation – helping to create a vision of reimagined work, or to develop disruptive technologies deployed via storyboards, user journeys, wire frames, or persona maps. Some organisations have gone so far as to hire science fiction writers to help imagine and explain moonshot thinking [p. 126].

Elliot Eisner (2008) explains that the arts are concerned with expressiveness, evoking emotion, generating empathic understanding, stimulating imagination that disrupts habits of mind and creates open-mindedness, and eliciting emotional awareness. In sum, the arts enable us to discover our humanity. Such an altruistic goal sits well with education for sustainability.

A succinct account of what the arts have to offer was discussed by arts educators Bucheli, Goldberg and Philips (1991):

> The arts can be, for both students and teachers, forms of expression, communication, creativity, imagination, observation, perception, and thought. They are integral to the development of cognitive skills such as listening,

thinking, problem-solving, matching form to function, and decision making. They inspire discipline and dedication. The arts can also open pathways toward understanding the richness of peoples and cultures that inhabit our world, particularly during this period of global change. The arts can nurture a sense of belonging, or community; they can foster a sense of being apart, or of being an individual. By acknowledging the role of the arts in our lives and in education, we acknowledge what makes individuals whole.

In the 1950s, Snow (1998) argued for a rapprochement of the cultures of science and the arts. Today, there is a wellspring of opinion that combining science and the arts in the form of STEAM education is essential for producing a creative, scientifically literate, and ethically astute citizenry and workforce for the 21st century (Boy, 2013; Edwards, 2010; Feldman, 2015; Piro, 2010). Already, the US, Korea and China have begun producing STEAM curricula for their respective nations (White, 2010). Recognising their limitations in developing students' higher-order abilities, visionary science educators are teaming up with their colleagues in the arts learning areas to design innovative interdisciplinary STEAM curricula and teaching approaches (Root-Bernstein, 2008; Sousa & Pilecki, 2013).

Early research studies on ground-breaking STEAM curricula in the US have demonstrated that learning activities integrating science, technology and the arts successfully engage minority and disadvantaged students, resulting in improved literacy and numeracy competencies (Clark, 2014; Stoelinga, Silk, Reddy & Rahman, 2015). In WA, a science/mathematics teacher in a Big Picture school integrated stories about everyday ethical dilemmas into her Earth Science lessons and demonstrated that at-risk students engaged in ethical decision-making while developing scientific knowledge and inquiry skills (Taylor, Taylor & Chow, 2013).

So, to sum up:

- STEAM education is not in opposition to STEM education; it enriches and expands the scope of STEM education.
- STEAM education is a curriculum philosophy that empowers science teachers to engage in school-based curriculum development.
- STEAM education involves teachers in developing a humanistic vision of 21st century education and their role as professionals.
- STEAM education provides a creative design space for teachers in different learning areas to collaborate in developing integrated curricula.
- STEAM education on a modest scale can be designed and implemented by an individual innovative teacher.
- STEAM educators can draw inspiration from project-based learning programs (for example, Holm, 2011).
- STEAM education engages students in *transformative learning*, which is based on five interconnected ways of knowing: cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, knowing in action (for details see Taylor, 2015).

Current STEAM projects

St Lukes Secondary College, Karratha. For the past 3 years, Rebecca Loftus, Head of Science, led an interdisciplinary team of teachers to develop a 7–10 STEAM curriculum. Learning areas represented are: science, drama, religious education, humanities and social sciences (HASS) and English. Rebecca is now enrolled in a PhD at Murdoch University and is investigating the impact of STEAM teaching on student engagement.

Cecil Andrews Senior High School. The State Government of WA awarded Cecil Andrews $4.8 million to build new STEM labs for the school. Under the visionary leadership of the principal, the school has embarked on a 7–10 STEAM curriculum development project. The Fogarty Foundation has awarded Professor Peter Taylor and Associate Professor Peter Wright (Murdoch University) a 3-year grant to support Cecil Andrews' STEAM curriculum project.

Christian Outreach College, Toowoomba. John McMath, Head of Science, is building on his doctoral research into socially responsible science, which investigated ethical dilemma pedagogy (Settelmaier, 2009) for engaging science students in higher-order thinking, and is working with colleagues in other learning areas to plan a STEAM curriculum for the school.

References

Australian Curriculum Assessment and Reporting Authority (ACARA). (2016). *Australian Curriculum: General Capabilities*. http://www.acara.edu.au/curriculum/general_capabilities.html

Australian Government. (2015). *National innovation and science agenda*. http://www.innovation.gov.au

Boy, G. A. (2013). *From STEM to STEAM: Toward a human-centred education*. Paper presented at the European Conference on Cognitive Ergonomics, Toulouse, France, 26–28 August 2013. http://ntrs.nasa.gov/search.jsp?print=yes&R=20130011666

Bucheli, M. R. J., Goldberg, M. R. & Philips, A. (1991). Symposium: Arts as education. *Harvard Educational Review, 61*(3), 25–26.

Clark, A. R. (2014). *Boston Arts Academy: Teaching and learning reports 2013–2014*. http://bostonartsacademy.org/site/wp-content/uploads/2012/08/2013_14_TeachingandLearningReports.pdf

Crutzen, P. J. & Stoermer, E. (2000). The Anthropocene. *Global Change Newsletter, 41*, 17–18.

Deloitte. (2015). *Tech trends 2015: The fusion of business and IT*. http://www2.deloitte.com/au/en/pages/technology/articles/tech-trends-2015.html

Edwards, D. (2010). *Artscience: Creativity in the post-Google generation*. Cambridge, Massachusetts: Harvard University Press.

Eisner, E. (2008). Art and knowledge. In J. G. Knowles & A. L. Cole (Eds.). *Handbook of the arts in qualitative research*. Thousand Oaks, California: Sage.

Feldman, A. (2015). *STEAM rising: Why we need to put the arts into STEM education*. http://www.slate.com/articles/technology/future_tense/2015/06/steam_vs_stem_why_we_need_to_put_the_arts_into_stem_education.html

Holm, M. (2011). Project-based instruction: A review of the literature on effectiveness in prekindergarten through 12th grade classrooms. *Rivier Academic Journal, 7*(2), 1–13. http://bie.org/object/document/project_based_learning_a_review_of_the_literature_on_effectiveness

Infosys. (2016). *Amplifying human potential: Education and skills for the fourth industrial revolution*. http://www.experienceinfosys.com/humanpotential

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate change 2014: Synthesis report – summary for policymakers*. Available at http://ipcc.ch.

National Research Council. (2011). *America's climate choices*. Washington, DC: The National Academies Press.

Office of the Chief Scientist. (2013). *Science, technology, engineering and mathematics in the national interest: A strategic approach*. Canberra: Australian Government.

Piro, J. (2010). Going from STEM to STEAM: The Arts have a role in America's future too. *Education Week, 29*(24), 28–29. http://www.edweek.org/ew/articles/2010/03/10/24piro.h29.html?qs=STEAM

PricewaterhouseCoopers. (2016). *21st century minds: Accelerator program*. http://www.pwc.com.au/stem.html

PricewaterhouseCoopers. (2015). *A smart move: Future-proofing Australia's workforce by growing skills in science, technology, engineering and maths (STEM)*. http://www.pwc.com.au/stem.html

Root-Bernstein, R. (2008). Arts foster scientific success: Avocations of Nobel, National Academy, Royal Society, and Sigma XI members. *Journal of Psychology of Science and Technology, 1*(2), 51–63.

Settelmaier, E. (2009). *Adding zest to science education: Transforming the culture of science classrooms through ethical dilemma pedagogy*. Saarbrucken, Germany: VDM.

Skutnabb-Kanga, T., Maffi, L. & Harmon, D. (2003). *Sharing a world of difference: The Earth's linguistic, cultural and biological diversity*. Paris: UNESCO. http://terralingua.org.

Snow, C. P. (1998). *The two cultures*. Cambridge, United Kingdom: Cambridge University Press.

Sousa, D. A. & Pilecki, T. (2013). *From STEM to STEAM: Using brain-compatible strategies to integrate the arts*. Thousand Oaks, California: Corwin/Sage.

Stoelinga, S. R., Silk, Y., Reddy, P. & Rahman, N. (2015). *Final evaluation report: Turnaround arts initiative*. Washington, DC: President's Committee on the Arts and the Humanities. http://pcah.gov

Taylor, P. C. (2015). Transformative science education. In R. Gunstone (Ed.). *Encyclopedia of Science Education* (pp. 1079–1082). Dordrecht, The Netherlands: Springer.

Taylor, E., Taylor, P. C. & Chow M. L. (2013). Diverse, disengaged and reactive: A teacher's adaptation of ethical dilemma story pedagogy as a strategy to re-engage learners in education for sustainability. In N. Mansour & R. Wegerif (Eds.). *Science education for diversity: Theory and practice* (pp. 97–117). Dordrecht, The Netherlands: Springer.

UNESCO. (2006). *Education for sustainable development*. http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/education-for-sustainable-development

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development.* https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

White, H. P. (2010). *STEAM not STEM whitepaper: An agreement on what drives the US economy in the future*. http://steam-notstem.com