Towards a re-positioning of STEM Education

A position paper arising from the Deakin University STEM Education Forum: Putting STEM Education under the Microscope

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Russell Tytler, Linda Hobbs, Vaughan Prain, Deakin University

Abstract

This position paper arises from discussions at the STEM Education Forum at Deakin University in October 2016, and draws also on outcomes from a major STEM Education Conference at the Deakin Waurn Ponds Geelong Campus the week before in which teacher voice was strongly represented. The paper analyses Australian public advocacy and policy documents and draws on research and new practices in STEM Education in Australian schools. We argue that policy directions should acknowledge generative school activity around STEM renewal, but also strengthen curriculum framing for mathematics and science as disciplines. We argue for research that identifies productive futures for STEM Education, acknowledging the complexity of STEM curriculum practices and purposes.

Background: The STEM Education Forum

"STEM" (Science, Technology, Engineering and Mathematics) has only a recent history in Australia but is increasingly used to advocate for changes to policy and practice in education and training, and research and development (Office of the Chief Scientist, 2013, 2016; Education Council, 2015). Advocacy of STEM is driven by government and industry and commercial interests, and is increasingly cited as crucial to re-purposing education in terms of students' contemporary learning needs and the skills required of industry (Hajkowicz et al., 2016). However, there is considerable ambiguity around the curriculum implications of this STEM focus, and need for critical analysis of what a productive future STEM program might look like that is different to current practice. We question some of the assumptions underpinning advocacy of STEM promotion and reform.

The Deakin STEM Education forum "Putting STEM Education under the microscope" involving 50 invited participants, focused on key questions surrounding: 1) the key drivers of the STEM curriculum agenda; 2) productive possibilities opened up for enlivening curriculum in the STEM subjects; 3) challenges and opportunities for the STEM subject disciplines; and 4) what can be learnt from the history of advocacy for curriculum integration. After an outline by Professor Russell Tytler of the history of concerns and advocacy for STEM in Australia, invited speakers provided individual inputs into the forum discussion. Dr Linda Hobbs reported on the richness of STEM work and enthusiasm of teachers reported in a STEM Education conference that was part of a Deakin University STEM innovation program. Professor Richard Lehrer spoke of the lack of evidence of science or mathematics learning coming from integrated STEM activity in the US, and provided a model by which mathematical data modeling could be used with science to enhance learning that retained the epistemic core of each discipline. Professor Peter Fensham drew on a long history of advocacy of 'science for all' to point out that advocacy of change inevitably involves debates about curriculum purposes and that innovation in curriculum has always been successfully opposed by disciplinary interests. Professor

Julian Williams underlined the problem with traditional mathematics curriculum practices and argued that students' home-knowledge should be the starting point for mathematics learning. Professor Günter Törner spoke of his experience as part of a large scale STEM initiative in Germany that links schools with industry. These inputs were interspersed with group discussion of the forum questions, leading to a final plenary session.

TOWARDS A RE-POSITIONING OF STEM EDUCATION

Policy drivers for STEM in education

Policy advocacy of STEM in Australia centres around claims that a future STEM-qualified workforce is needed for national wealth creation. This advocacy is fueled also by concern at decreasing student engagement in STEM subjects and pathways, indicative in reducing comparative mathematics and science performance internationally (Thomson, S., Wernert, N., O'Grady, E., Rodrigues, S., 2016; Thomson, S., De Bortoli, L. & Underwood, 2016). The other side of this advocacy is that future workers will increasingly need STEM skills and capabilities such as collaborative problem-solving, creativity, and digital literacy to be competitive in a future job market of higher level skills, and where flexibility and adaptation are crucial for ongoing employment (Hajkowicz et al. 2016). This wider set of purposes towards capabilities and a 'turn to practice', rather than traditional conceptual outcomes of school science and mathematics, prompts calls for integrated STEM curricula based around authentic tasks, with engineering/technology design and digital literacies added to the mix. Such additions reflect the inclusion of engineering concepts in the new US science standards, and concern over low levels of engagement in engineering and computer science pathways in Australia (Marginson, Tytler, Freeman & Roberts, 2013). Much of the critique of current school practices embodied in STEM advocacy reflects a perceived failure of school mathematics and science to engage students, largely seen to be due to prevailing transmissive pedagogies and crowded and abstract curricula that fail to reflect contemporary practice and ideas within STEM disciplines.

Moves toward re-focused STEM curricula that better reflect contemporary STEM practices and include integrated activity are driven in part by:

a) government investment in STEM initiatives that include inter-disciplinary activity (http://invenio.deakin.edu.au/deakin-to-lead-secondary-stem-catalysts-project/);

b) teacher enthusiasm for activities that are seen to engage students;

c) commercial interests (e.g., Criterion http://www.criterionconferences.com/event/improvingstemeducation/); and

d) some advocacy by the research community (e.g., Vasquez, 2015) .

Challenges for STEM curriculum reform

A major system level barrier to reforming STEM subjects to focus on capabilities for future life skills or workplaces is the contemporary accountability emphasis evident in standardized test regimes. This tends to undermine the curriculum flexibility implied by inter-disciplinary project activity or a focus on creativity and collaborative problem-solving. Framing mathematics and science curricula in strict disciplinary terms, with extended, structured outcomes that act against setting and pursuing contextual problems, is a further barrier.

There are also multi-layered concerns raised about inter-disciplinary conceptions of curriculum. While activities such as collaborative design projects have been found to engage students, concerns are raised about the quality of mathematics and science learning (Honey et al., 2014) and at a theoretical level about the epistemic coherence of much of this activity (Lehrer, 2016; Clarke, 2014). Much of this critique rests on the question of whether STEM can be seen as a meta-discipline with distinctive discursive / material conceptual systems by which knowledge is created, or whether inevitably the separate disciplines must remain distinct even when used in inter-disciplinary projects and problem-solving. There is also a long history of failed attempts to develop integrated curricula because of the weight of tradition, and the realities of school practices (Venville, Wallace, Rennie & Malone, 1998). Practical and cultural factors always make change in schools difficult – the inertia of traditions in pedagogy and content cemented in arrangements at multiple levels – teacher histories, teacher training, timetables, status, and misconstruals of what it is to know. Traditional mathematics and science curricula tend to privilege abstracted knowledge and have narrow versions of practice antithetical to the calls for creative problem solving (Williams, 2016). In the end, separated disciplinary perspectives have always prevailed (Fensham, 2016),

At the forum an important question was thus raised: 'What is new and different now that might give us an expectation that 'STEM' will prevail as a recognized curriculum entity or approach?' From the forum discussion and literature analysis a number of factors can be identified that arguably give some promise of curriculum change that better represents contemporary practice in the STEM disciplines. These include:

a) changes in the way knowledge is generated and accessed that break down traditional reliance on teacher delivery;

b) a new urgency felt by the STEM community to engage with schools in bringing more authentic practice (e.g. ; http://www.chiefscientist.gov.au/2016/01/spi-2016-stem-programme-index-2016-2/);

c) indications that the STEM construct has been used productively by other countries further down the track than Australia in this regard, to generate new and different activity (e.g. Torner, 2016); and

d) what seems to be a new enthusiasm in schools to engage in STEM activity that often involves cross disciplinary planning with emphases on collaborative project-based problem-solving.

In addition, new understandings of the processes by which knowledge is produced in science and mathematics provides us with new directions for reform within and across these disciplines (Latour, 1990; Nersessian, 2008; Lehrer & Schauble). There is a need to investigate how teaching and learning approaches in mathematics and science can be better harnessed to support collaborative, creative problem-solving and critical reasoning processes promoted by the STEM agenda.

STEM innovation in schools

Teachers of mathematics, science and technology in Australia are seeing STEM as a way to attend to engagement and learning issues in the school. While there is no STEM curriculum per se, existing projects are being rebadged, and new programs developed, with new subject alliances and connections with community/industry. Most noticeable is the elevation of previously marginalised subjects, such as technology and systems engineering subjects. Despite the 'failures' of integrated education over many decades there exists in many Australian schools teachers with commitments to progressive educational practices who have continued to support and explore approaches that cut across subject boundaries, or embrace project based work within subjects. We argue that such teachers will be one key to the success of a STEM curriculum agenda that challenges traditional teaching and learning practices in the core STEM disciplinary subjects of mathematics and science. However, teachers currently involved in inter-disciplinary STEM practices are struggling to articulate the learning that arises despite the obvious engagement of students in collaborative problem solving. There is a need for research, and academic leadership in articulating the core epistemic processes underpinning productive STEM innovation and their relation to discipline-based epistemic processes. Such research and leadership is needed to support teachers in planning and conceptualizing the nature of the learning associated with the increasingly rich and varied STEM practices that are growing in schools.

Developing a coherent conception of STEM Education

In framing a way forward for such research and for policy framing in STEM, drawing on forum discussions, a reading of the literature around STEM, and our own experience in the field, we propose the following principles:

1. We need to acknowledge STEM as an emerging practice in schools, and recognize and investigate the rich diversity of emerging STEM goals, methods, practices, and outcomes to articulate productive ways forward for curriculum framing and school practices. In doing this we argue a need to resist any pre-emptive reductive definitions of what a STEM practice might be, but rather accept the multiplicity of school arrangements and learning goals that are developing. The relationship between inter-disciplinary project work and authentic tasks within subject disciplines, and between content and pedagogy, for instance, may be multi-faceted.
2. We need to acknowledge that the broad STEM agenda has led to some promising signs of curricular renewal through STEM in the Australian context that has the potential to provide a productive pathway to address economic and policy imperatives.
3. In order to ensure the sustainability of these emerging practices and commitments there is a need for growing system support at multiple levels including curriculum policy framing, teacher professional learning, resources exemplary of school STEM innovation, and assessment.
4. There needs to be a targeted research agenda alongside the work with schools that focuses on:
    a. Identifying common themes underlying the multiple approaches to STEM, in particular developing a common language around STEM that can be applied flexibly in meeting the needs of schools;
    b. Explaining effective teaching and learning strategies and learning gains associated with a STEM focus;

c. Investigating new teaching and learning approaches to STEM disciplinary subjects that reflect their core epistemic processes in supporting the collaborative, creative problem solving and critical reasoning practices underpinning calls for STEM reform;

d. Identifying changes to teacher and student attitudes to and understandings of science, mathematics and technologies, associated with STEM reform;

e. Developing assessment processes that capture and support the broader range of student reasoning and problem solving outcomes that drive calls for STEM reform;

f. Identifying school leadership and teacher collaboration practices that enable sustainability of curricular changes in STEM approaches;

g. Investigating the nature of effective teacher professional development in STEM teaching and learning;

h. Analyses of effective models for stakeholder inputs into STEM education, including government and non-government, and industry and community support; and

i. Articulation of an approach to STEM for all, and the potential value of STEM to low SES and under-represented groups in mathematics and science.

References

Clarke, D. (2014). Disciplinary Inclusivity in Educational Research Design: Permeability and Affordances in STEM Education. Invited keynote at the International STEM conference, Vancouver, July 2014. http://www.djclarke.iccr.edu.au/

Education Council. (2015). National STEM school education strategy: A comprehensive plan for science, technology, engineering and mathematics education in Australia. Canberra: Education Council. http://www.scseec.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf

Fensham, P. (2016). An historical perspective on STEM as a schooling goal. Paper delivered at the forum: Putting STEM Education under the microscope. Deakin University, Melbourne, October.

Hajkowicz, S., Reeson, A.. Rudd, L., Bratanova, A., Hodgers, L., Mason, C., & Boughen, N. (2016). Tomorrow’s digitally enabled workforce: Megatrends and scenarios for jobs and employment in Australia over the coming twenty years. CSIRO.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, D.C.: National Academies Press.

Latour, B. (1990). Drawing things together. In M. Lynch and S. Woolgar (Eds.), Representation in scientific practice (pp. 19–68). Cambridge, MA: MIT Press.

Lehrer, R., (2016). Perspectives on Integrating Elementary STEM Education. Paper delivered at the forum: Putting STEM Education under the microscope. Deakin University, Melbourne, October.

Lehrer, R., & Schauble, L. (2003). Origins and evolution of model-based reasoning in mathematics and science. In H. Doerr & R. Lesh (Eds.), Beyond constructivism: A models and modeling perspective. Mahwah, NJ: Erlbaum.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons*. Melbourne: The Australian Council of Learned Academies. www.acola.org.au.

Nersessian, N. (2008). Model-based reasoning in scientific practice. In R. Duschl & R. Grandy (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 57-79). Rotterdam: Sense Publishers.

Thomson, S., De Bortoli, L. & Underwood, C. (2016). PISA 2015: A first look at Australia's results. Camberwell: ACER. Retrieved Jan 2016 at https://www.acer.edu.au/ozpisa/pisa-2015

Thomson, S., Wernert, N., O'Grady, E., Rodrigues, S. (2016). TIMSS 2015: A first look at Australia's results. Camberwell: ACER. Retrieved Jan 2016 at http://apo.org.au/node/70904

Törner, G. (2016). Business communities supporting STEM innovation in German schools. Paper delivered at the forum: Putting STEM Education under the microscope. Deakin University, Melbourne, October.

Vasquez, J. (2015). STEM: Beyond the acronym. *Educational Leadership*, 11-15.

Venville, G., Wallace, J., Rennie, L. J., & Malone, J. (1998). The integration of science, mathematics, and technology in a discipline-based culture. *School Science and Mathematics*, *98*(6), 294-302.

Williams, J. (2016). Becoming un-Disciplined by Science and Mathematics: the life and death of STEM. Keynote address delivered at the STEM Education conference: Building STEM capability in schools. Deakin University, Geelong, October.