

Innovation and Entrepreneurship as Economic Change Agents: The Role of STEM Education in Australia

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Abstract

Science, technology, engineering and mathematics (STEM) are considered by most western countries as the key areas for ensuring economic prosperity into the future. The recent establishment in Australia of the Department of Industry, Innovation and Science (DIIS) along with a new *National Innovation and Science Agenda* indicate that political goodwill and policy is aligned to create and drive innovation and entrepreneurship. So what is the role of STEM education in this emerging directive? In our view, STEM education is pivotal in ensuring that our future thinkers are responsive and adaptable to emerging opportunities and challenges. Yet, an analysis of government policy highlights a fairly traditional view regarding the role of STEM education in supporting the broader ideas around innovation and entrepreneurship. This theoretical position paper interrogates emerging Australian policy to explore how the role of STEM education is conceived in these new government directives.

Keywords: STEM education; innovation; entrepreneurship, creativity, policy

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Introduction

The majority of countries consider a skilled workforce in science, technology, engineering and mathematics (STEM) as a high priority for ensuring future economic prosperity in a competitive global economy. Australia is no exception with many reports published over the last decade reiterating this same priority (Australian Academy of Science, 2011; DEST, 2006; Office of the Chief Scientist, 2012). In particular, these reports emphasise the critical role STEM plays in relation to *innovation* and *entrepreneurship* as the major change mechanisms for economic prosperity. In Australia’s case, the recently published *Australian Innovation System Report* (Office of the Chief Economist, 2015) states that:

To continue to prosper, Australia must find new sources of wealth. As an advanced economy, we expect that further advances in national competitiveness and economic growth, including employment growth, will come primarily through innovation. Innovation is the core driver of business competitiveness and productivity. It supports economic growth, exports and job creation. Facilitating innovation involves enabling disruptive technologies and globalisation to access more opportunities for new products, new industries and new markets (p. 1).

The aim of this theoretical position paper is to explore how innovation and entrepreneurship, which are essentially economic terms, are connected to STEM, and more particularly to STEM education, as articulated in recent Australian government policies.

Innovation, creativity and entrepreneurship

Innovation as a term is used frequently, yet rarely defined. It is closely linked with creativity, which also has multiple meanings. For the purposes of this paper, we reviewed the economics literature given that it is this context that is driving the STEM agenda in Australia. Within the literature, creativity is considered as “*the production of novel and useful ideas by an individual or small group of individuals working together*” (Amabile, 1988, p.126). When referred to in relation to thinking, creativity is often characterised by an apparent lack of connection to other ideas with phrases like *random thoughts*, *thinking outside the square*, *guesses* and *intuition* espoused as common attributes. Because of the random generation of creative ideas it is not considered appropriate to place parameters around the creative process as it may ‘restrict thinking’. Innovation is linked to creativity being defined as the “*successful implementation of creative ideas, particularly in an organisation*” (Amabile, 1988, p.126). What is apparent from these definitions is that while innovation is built on creative ideas, it is

also importantly about the successful *use* or *implementation* of those ideas. So, how then does entrepreneurship fit together with creativity and innovation?

Stevenson (cited by Eisenmann, 2013, p.1) defines entrepreneurship as “*the pursuit of opportunity beyond resources controlled*”. It is only by unpacking this definition that the complex nature of entrepreneurship becomes evident. For example, *pursuit* highlights the singular focus and sense of urgency that drives the entrepreneur. *Opportunity* refers to the novel offering available to the entrepreneur that might involve: (i) pioneering a new product; (ii) devising a new model; (iii) creating better or cheaper versions of an existing product; or (iv) targeting new customers for an existing product. Since entrepreneurship is often used in conjunction with new start-up businesses, consideration of available resources is critical. So, the third element of the definition *beyond resources controlled* implies that resources will be constrained. To explain this further, in any new venture the founders have control over their own human, social and financial capital. However, with high potential ventures (common for entrepreneurs), the founders must mobilise more resources than they have or control, such as production facilities, distribution channels, and working capital. When founders pursue opportunities for their own ventures, they must often extend beyond the resource base that they control, which ultimately leads to greater risk. This risk might take the form of demand risk, technology risk, execution risk, or financial risk. Ultimately, success in the ventures relies on the founder’s ability to manage uncertainty even though certain risks cannot be controlled. The result is that the founders (entrepreneurs) need to be inventive, creative, opportunistic, and persuasive as they rarely have all the resources required to source the venture alone. Hence, the phrase “*beyond controlled resources*”.

In linking these three constructs together (see Figure 1), it is creativity that stimulates both innovation and entrepreneurship. So, while innovation and entrepreneurship are often seen as the actual agents of change, in an economic sense, they rely on the original construct of creativity or a creative idea. This raises the question as to where creativity is actually developed and nurtured within society generally, but especially in economics and education? In the next section, we introduce the notion of an innovation system and consider Australia’s policy context for developing as an innovation system.

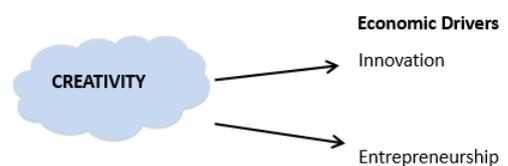


Figure 1. Creativity foundational for innovation and entrepreneurship

The Innovation Policy Context in Australia

A key component of our analysis involves an examination of the innovation system that operates within Australia and the role STEM education *is contributing* and might *be expected to contribute* to the innovation system in the future. For the purposes of this paper, an innovation system is defined as:

...an open network of organisations that interact with each other and operate within framework conditions that regulate their activities and interactions. The three components of the innovation system — networks, innovation activities and framework conditions — collectively function to produce and diffuse innovations that have, in aggregate, economic, social and/or environmental value (Office of Chief Economist, 2014, p.14).

Within an innovation system, *networks* refer to geographic clusters of economic activity, business associations and/or supply chains. *Innovation activities* include training, research and development, venture capital investment, and patenting activity. *Framework conditions* identify the range of macro-economic, cultural, educational, and policy settings that contribute to nurturing innovation. Clearly, there is a role for STEM education here through innovation activities, such as training, research and development, and in framework conditions through STEM education policy.

So, herein lies the first issue concerning policy. Our previous research (Panizzon, Corrigan, Forgasz & Hopkins, 2015) highlighted a lack of clarity in the way that STEM is defined across government, industry, business, and educational sectors in Australia and internationally. The result is that the data varies quite significantly depending on what sub-disciplines are included or excluded from any analysis thereby resulting in inconsistencies in findings regarding participation rates in STEM education and STEM-related careers. As such, making any comparisons across government reports at a federal and state level in Australia was not possible.

However, an examination of the current framework conditions existing in Australia provides evidence of a number of recent incremental advances in government policy and strategies. For example, the *Australian STEM Workforce report* from the Office of the Chief Scientist (2016) has attempted to clarify the ambiguity around STEM by providing clear definitions of Science (inclusive of the natural and physical sciences, agriculture, environmental science and related studies), Technology (information technology), Engineering (engineering and related technologies) and Mathematics (mathematical sciences). It is important to note that medicine and the health-related careers are not included in the discipline of science in this report.

This is an important decision as these two areas encompass a large number of students thereby dramatically altering the STEM data. While there is clarification in these areas, it also raises other contradictions, such as the way in which technology is conceptualised.

Technology provides goods and service to satisfy real world needs, operating at the cross-section of science and society. Information and communications technology is playing an ever-increasing role in our society and provides enabling capacity to the other STEM disciplines. The output of the technology provided must eventually stand the test of users and the marketplace.

Engineering draws on scientific, mathematical and technological knowledge and methods to design and implement physical information-based products, systems and services that address human needs, safely and reliably. Engineering takes into account economic, environmental, and aesthetic factors (Office Chief Scientist, 2016, p1).

The issue here is that in defining Technology as ICTs only and aligning the broad-based technologies more closely with engineering, a critical opportunity is lost to accentuate the important interdependence that exists between technology and the sciences in building new knowledge and understandings of our world.

Another example of a positive change in Australian policy is *The National Innovation and Science Agenda* (Australian Government, 2015) released in December 2015, which is centred around the four key pillars of *culture and capital, collaboration, talent and skills, and government as an exemplar*. In particular, the talent and skills pillar focuses on STEM education with a number of initiatives specified in the policy document: (i) inclusion of computer coding being taught across different year levels in schools; (ii) revision of the Australian Curriculum to allow increased class time for the teaching of science, mathematics and English; and, (iii) the expectation that all new primary teacher graduate with a subject specialisation in STEM or English. These so called 'new' initiatives are strategies for ensuring a STEM pipeline of students when combined with the existing initiatives, such as science competitions, the Scientists in Schools program (Rennie, 2012), and professional development programs that are readily available for teachers in science and mathematics.

A second key policy document specifically for schools and endorsed by the Prime Minister is the *National STEM School Education Strategy 2016-2026*, which was also released by the Australian Education Council. This strategy highlights two main goals for STEM education into the future: (i) to ensure that all students finish school with a strong foundational knowledge in STEM and related skills; and (ii) to ensure that students are inspired to take on

more challenging STEM subjects (e.g., physics). It is an expectation that these goals will be achieved through five key actions:

1. Increasing student STEM ability, engagement, participation and aspiration;
2. Increasing teacher capacity and teaching quality in areas of STEM;
3. Supporting STEM education opportunities within school systems;
4. Facilitating effective partnerships with tertiary education providers, businesses, and industries; and
5. Building a strong evidence base.

Again, what is clearly overlooked in this policy document is clarity around what constitutes the STEM knowledge that is foundational in the strategy. In other words, many of the issues identified in the past in relation to the ambiguity around STEM still pervade. Hence, absence of this clarification and a shared understanding of the nature and role of STEM for all stakeholders inhibits STEM education from taking a central role in actually contributing to innovation and entrepreneurship into Australia's future.

Further examination of these key actions exposes that these are not new but merely the strengthening of already existing actions and strategies. While this is positive in that there is continuing support for initiatives that are already 'up and running' it raises the question as to how do these align to the focus on creativity, innovation and entrepreneurship articulated in the *National Innovation and Science Agenda*? In our view it is still not clear how continuing along the same path will allow STEM education to meet the needs of Australia's innovation system.

Analysing the range of STEM activities in Australia

In 2016, the Office of the Chief Scientist in conjunction with the Australian Industry Group (Ai Group) published the STEM Programme Index (SPI) 2016. Within this index there are over 250 active programmes catering for schools and students across Australia provided by businesses, universities, science and education agencies, and government. It is important to state that the introduction to the index acknowledges that the compilation is not a definitive summary with other programmes available. A review of the 146-page document is evidence that there are extensive opportunities available for students of all year levels and the general public to engage in what are categorised as STEM activities.

As part of our exploration around the potential to nurture innovation, entrepreneurship and creativity the characteristics identified by each programme were categorised and tallied (see Table 1). This involved the categories identified in the SPI 2016 (horizontal headings across the top of table) being matched against our particular codes (vertical headings along the side of the table). These codes emerged from the data itself so were not pre-determined. In the analysis, any one programme might be linked to more than one code. For example, *Primary Connections: Linking Science with Literacy* (a teacher resource consisting of a series of work books) was categorised in the Primary School sector and coded into literacy, content, innovation, inquiry-based approach, and resource based on the description outlined in the SPI 2016.

Table 1. Codings and frequencies from analysis of the SPI Index 2016

Codings from the analysis	As categorised in the index SPI Index 2016					
	Science (N=88)	Digital technology and IT (N=46)	Engineering and technology (N=21)	Mathematics (N=36)	STEM (N=70)	Entrepreneurship (N=4)
Advice	7	5	2	0	1	1
Career	2	18	9	3	26	1
Communications	10	1	0	0	4	0
Creativity (including creative problem- solving)	6	4	2	2	12	0
Critical thinking	3	3	2	0	3	0
Curiosity	0	1	0	0	1	0
Entrepreneurship	0	3	0	0	2	4
Independent thinking	1	2	0	0	2	0
Indigenous	4	0	1	1	8	1
Innovation	1	2	1	0	12	0
Inquiry-based	9	2	0	2	13	10
Literacy	1	0	0	0	1	1
Motivation	28	6	4	12	23	0
Product/resource	0	3	3	0	5	5
STEM as a Human Endeavour	1	0	4	2	9	0
STEM content	38	24	5	33	32	0
STEM investigation	27	14	9	10	24	2
STEM literacy	2	0	0	1	2	0

In reviewing this table and the nature of the programmes some clear trends emerge:

1. Disciplined-based activities clearly focus on either content or the processes of science (e.g. STEM investigations).
2. There is considerable emphasis around enhancing student motivation with a message that increased motivation will lead to increased participation in STEM.
3. Programmes with a multidisciplinary focus tended to concentrate on teams and collaboration using problem-based approaches.
4. There is also a large focus on careers in programmes with the majority targeting females.
5. Digital and IT programmes tend to have a broader range of aims that focus also on the thinking involved in the process of producing an end-product more than other areas.
6. The entrepreneur programmes are more general in nature with only one specifically targeting the STEM area.
7. There is a distinct absence around the explicit role of creativity in the majority of programmes.

If Australia needs creativity, innovation and entrepreneurship where are these being nurtured in this incredible array of activities that are currently available to students, teachers and the general public as summarised in the SPI Index 2016? There is clearly considerable funding aligned to these activities but one needs to ask: how are they actually contributing to the future in STEM education and the need for our students to ‘think outside the square’.

Conclusion

In this exploration of current policies around STEM education and the way in which it will support Australia in terms of its innovation system, we identify a distinct lack of innovation. While some real gains are evident in the areas of business and funding, this is not the case for STEM education. There still appears to be a large disconnect between the national agenda in Australia, which is similar to many developed western countries, and the role of STEM education in realising the national agenda. The link between innovation and entrepreneurship with STEM education remains unclear requiring significant clarification and thought if we are to actually align with the knowledge, aptitudes and skills required to support Australia’s future and provide valuable opportunities for all Australians.

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