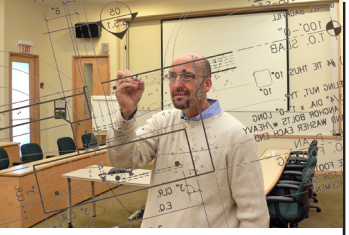

Geography and STEM

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One of the questions being asked in schools is the extent to which Geography can be considered a STEM subject. While such a question might be driven by those strategic opportunists seeking to elevate the status of the subject within the school's curriculum, or as a means of leveraging an increase in funding, it is a question worth serious attention.

This paper argues that Geography has the potential to play an important role in advancing the objectives of STEM (Science, Technology, Engineering, and Mathematics) in the Australian educational context. In doing so, Geography's place within the humanities is in no way diminished. The humanities remain central to our understanding of the social world in which we live. It also provides important insights into the context within which science gains its significance and from which it draws its authority. Geography, given that it straddles both the physical and human sciences, can advance both the humanities and STEM.

STEM is defined as a national strategy promoting a cross-disciplinary, multidisciplinary and integrated approach to learning. The focus on STEM aims to build Australia's future competitiveness in a rapidly changing global economy through using the lenses of STEM to develop individual and national capacity to respond to challenges around productivity and economic wellbeing. There is an emphasis on critical and creative thinking to solve real-world challenges (Australian Curriculum, Assessment and Reporting Authority (ACARA), 2016; Education Council, 2015; Office of the Chief Scientist, 2013, 2014; Seikmann & Korbel, 2016). In short, the focus on STEM is being driven by an economic imperative.

The emphasis on STEM is not unique to the Australian educational context. In the United States of America, for example, authorities have assessed STEM as being critical to the future growth of the economy and essential for the nation's global competitiveness. It has also been identified as a field in which American students don't excel. As a result, funding has been increased for STEM, often at the cost of support for other subject areas.

The status of Geography vis-à-vis STEM is ambiguous for two principal reasons.

1. There continues to be debate about what actually constitutes STEM. Does it, for example, include Geographical Information Systems (GIS) and Cartography? Does the field of Geosciences (and by definition most of physical geography) qualify as STEM?
2. Geography is a broadly interdisciplinary discipline that now embraces at least four sub disciplines – two of which (Physical or Environmental Geography) are clearly STEM. The other two, which are firmly grounded in the humanities, are Human and Cultural Geography.

In search of definitional clarity

Any discussion regarding Geography's contribution to STEM requires some degree of contextual and definitional clarification. What is Geography and how has it been traditionally positioned within the total school curriculum?

Geography has been defined by Australia's National Committee for Geographical Sciences (2018) as a wide-ranging and dynamic discipline where phenomena from the natural world, social world, and the humanities are integrated and studied through the perspectives of place, space, and environment. As a discipline, Geography provides us with an understanding about the world around us, for example through exploring the diversity of environments, places, peoples and cultures, the inequalities existing within and between places, dependence on the environment for survival, attachment to place, and connections between places and people throughout the world. Furthermore, Geography offers students the opportunity to develop literacy and numeracy skills in context together with an understanding about the significance of the environment, a set of personal capabilities including critical and creative thinking, and distinctive ways of thinking (Maude, 2019).

Implicit in this definition of Geography is the integrating nature of the discipline. Geography spans both the physical and human sciences. As such, it provides a unique conceptual lens

through which to study, and better understand, a diverse range of physical and human phenomena.

In terms of its curriculum positioning, Geography is, at a national scale, typically identified as a subject within the Humanities and Social Sciences (HASS) learning area with a focus on inspiring curiosity and wonder about the diversity of the world's places, peoples, cultures and environments, and encouraging active citizenship towards creating a socially just and sustainable future (ACARA, 2013a; Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA), 2008; National Committee for Geographical Sciences, 2018).

HASS is defined in the Australian Curriculum structure as a learning area comprised of several subjects including Geography, History, Civics and Citizenship, and Economics and Business. Learning focuses on consideration of future challenges through the study of human behaviour and interaction in social, cultural, environmental, economic, historical and political contexts, from the personal to global scale (ACARA, 2013b; MCEETYA, 2008). It should be noted that across states and territories the name and inclusion of HASS-identified subjects varies slightly.

An integrated curriculum refers to the purposeful connection or links being made between what is being learnt in one subject with another – i.e. meaningful teaching, learning and assessment activities are designed across several subjects or disciplines (Dowden, 2014; Smith & Lovat, 2006). An integrated curriculum allows complex real-world problems to be solved through critical and creative thinking using a cross-disciplinary or multi-subject lens (Acedo & Hughes, 2014).

The literature suggests that Geography provides a bridge between the social sciences and biophysical sciences but is characterised by the analytical, critical and speculative methodologies of the humanities through determining the impact of place, space and environment on the human condition (ACARA, 2013b; Sorensen, 2009). As the national curriculum development process continued, and further research emerged, the *Foundation to Year 10 Australian Curriculum: Geography* was written to have specific points of connection and complementarity to the *Foundation to Year 10 Australian Curriculum: Science* and the *Foundation to Year 10 Australian Curriculum: Mathematics* (Caldis, 2019).

Science-based content unique to the Australian Curriculum: Geography

Alaric Maude, the Lead Writer of the *Shape Paper Australian Curriculum: Geography* (ACARA, 2011), identified, in an undated briefing paper prepared for the National Committee for Geographical Sciences, a number of science-based topics covered by the Australian Curriculum: Geography (and its HASS replacement) but not in the Australian Curriculum: Science, or not at the same depth. These topics are also identified in Geography: Shaping Australia's Future (National Committee for Geographical Sciences, 2018).

These topics include:

- climate types (Year 3) – in Science the only mention of climate is in relation to climate change;
- vegetation types and the effects of vegetation on the environment (Year 4) – vegetation is not mentioned in Science;
- quantity and variability of Australia's water resources compared with other continents (Year 7);
- nature of water scarcity and ways of overcoming it (Year 7);
- causes, impacts and responses to an atmospheric or hydrological hazard (Year 7);
- causes, impacts and responses to a geomorphological hazard (Year 8);
- characteristics and distribution of biomes (Year 9);
- human alteration of biomes to produce food, industrial materials and fibres (Year 9);
- environmental, economic and technological factors that influence crop yields in Australia and across the world (Year 9) – Science has this elaboration in Year 8 describing how technologies have been applied to modern farming techniques to improve yields and sustainability;
- challenges to food production, including land and water degradation, shortage of fresh water, competing land uses, and climate change for Australia and other areas of the world (Year 9);
- capacity of the world's environments to sustainably feed the projected future global population (Year 9) – the only mention of agriculture in the Science curriculum is this elaboration in Year 8: describing the impact of plant cloning techniques (asexual production) in agriculture such as horticulture, fruit production and vineyards;
- human-induced environmental changes that challenge sustainability (Year 10) – Science has this elaboration in Year 7: considering how human activity in the community can have positive and negative effects on the sustainability of ecosystems; and
- study of environmental change in a particular type of environment (Year 10).

Note that the Geography content is from content descriptions, which are mandatory while the Science content is in elaborations, which are not.

Some scientific concepts and terms are taught in the Geography curriculum but not in Science. These include:

- climate;
- evaporation and evapotranspiration;
- water balance;
- vegetation;
- biomass;
- biome;
- net primary productivity; and
- land and water degradation.

Maude, in the same briefing paper, identifies a number of skills featured in the Geography curriculum that are mathematical or technological. These include:

- representing data in a range of appropriate forms, for example, climate graphs, compound column graphs, population pyramids, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies (Years 7 and 8);
- representing multi-variable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies (Years 9 and 10);
- representing spatial distribution of different types of geographical phenomena by constructing appropriate maps at different scales that conform to cartographic conventions, using spatial technologies as appropriate (Years 7 and 8);
- representing spatial distribution of geographical phenomena by constructing special purpose maps that conform to cartographic conventions, using spatial technologies as appropriate (Years 9 and 10);
- interpreting geographical data and other information, using qualitative and quantitative methods, and digital and spatial technologies as appropriate, to identify and propose explanations for spatial distributions, patterns and trends, and infer relationships (Years 7 and 8);
- interpreting and analysing multi-variable data and other geographical information using qualitative and quantitative methods, and digital and spatial technologies as appropriate, to make generalisations and inferences, propose explanations for patterns, trends, relationships and anomalies, and predict outcomes (Years 9 and 10).
- Learning to construct, interpret and use maps helps to develop children's spatial intelligence. It is now well established that this is a separate type of intelligence, additional to mathematical intelligence and verbal intelligence (Ness, Farenga, & Garofalo, 2017). Spatial intelligence, or the ability to think spatially, is important in everyday life, but is also used in mathematics, several fields of science, architecture, engineering, urban planning and geography. Geography has a significant role to play in developing these spatial skills. Liben (2007, p. 221), for example, argues that 'geography education in general, and map education in particular, can have an important place in developing spatial thinkers'. Mapping is therefore much more about developing spatial thinking skills than learning how to find places and navigate from one place to another. Spatial thinking is defined as:

  … the use of spatial concepts, spatial representations, and processes of reasoning to conceptualize and solve problems. Following this definition, spatial thinking involves the ability to visualize and interpret data about space that is then encoded and stored in memory. This definition emphasizes language (knowing and using spatial concepts such as location, distance, scale); being able to understand spatial representations such as maps, graphics, and diagrams; and the application of these to problem solving, both personal and academic. This is related to the development of a spatial habit of mind. This is the predilection to think spatially and to apply the skills required to engage in reasoning with concepts of space and visual representations. (Bednarz 2018, p. 3)

Also worthy of note is the inquiry-based foundations of the Australian Curriculum: Geography (and the Geography components of HASS). This methodological framework parallels that underpinning scientific inquiry, commonly referred to as the *scientific method*. The step-by-step approach progresses from identifying and defining a problem or issue, formulating a tentative hypothesis, gathering data to test the hypothesis, and interpreting results objectively. The skills set developed by students engaged in inquiry are generic in the sense that they can be applied in a range of contexts, including those beyond school.

Geographical inquiry is defined in the Australian Curriculum: Geography as "the process by which students learn about and deepen their holistic understanding of their world". It is described as

involving individual or group investigations that start with geographical questions and proceed through the collection, evaluation, analysis and interpretation of information to the development of conclusions and proposals for action. The inquiries undertaken may vary in scale and geographical context.

The skills students deploy in these inquiries or investigations, both within the classroom and during fieldwork, are developed from K (Foundation) to Year 12. They include formulating questions and research plans; recording and presenting data skills; and using a variety of spatial technologies. In applying these skills, students learn to think critically about the methods used to obtain, represent, analyse and interpret information, and communicate findings.

By Years 7 and 8, students are able to present findings, arguments and ideas in a range of communication forms selected to suit a particular audience and purpose, using geographical terminology and digital technologies as appropriate. By Years 9 and 10, students progress from the presentation of ideas to the formulation of explanations. The means of communication used is selected based on its effectiveness and its suitability to the audience and purpose.

The stages of the investigations students complete are: observing, questioning and planning; collecting, recording, evaluating and representing; interpreting analysing and concluding; communicating; and reflecting and responding. As noted above, these stages mirror the inquiry sequence applied in science. In this regard Geography can be seen to make an important contribution to the development of these STEM-related competencies.

In defence of the Geography's status and positioning within the humanities

Any discussion of Geography's contribution to STEM in no way diminishes the discipline's status within the social sciences and humanities. This is an important point to make because, as Professor Iain Hay (2016) notes, the humanities are under assault from an increasingly utilitarian worldview and from conservatives preoccupied with cultural conflict. The latter argue that the humanities have been captured by the progressive left who see them as a vehicle for the transformation of society.

The trend towards a more utilitarian educational environment is reflected in the choices students make. Many students choose vocationally-focused degrees that hold the offer of financially rewarding careers. This is contrary to the flexibility of the humanities and skills set developed by those studying a related discipline. There is, as Hay argues, a degree of "vocational and economic pragmatism" in the decisions made by students, reinforced by the encouragement of the political class and parents. Governments see STEM-related subjects as central to the future economic wellbeing of nations. This, at least in part, is driven by the need to remain internationally competitive in an increasingly integrated global economy.

The focus on STEM has resulted in a decline in public and private funding of the humanities, especially in the area of research. At the same time, funding for mathematical and physical sciences, biological sciences, medical sciences and engineering has grown (Hay, 2016). This shift in funding has been cheered on by conservative commentators who fuel the devaluing of the humanities for their own ideological ends.

Maude (2019) argues that the lack of formal recognition of Geography as a STEM subject is a contributing factor to the declining student candidature in the discipline and a confused understanding about rigorous career pathways related to Geography. To counter this, the National Committee for Geographical Sciences (2018) suggests that the discipline's profile should be extended beyond the humanities and that it be formally acknowledged that its significant science content qualifies geography as a partial STEM subject. An expanded lens of understanding about Geography will increase its visibility, integrity and profile. In so doing, geographical knowledge and understanding will be enhanced within the Australian population, together with a greater appreciation about the important university pathways and career trajectories offered by the study of geography to support the productivity and relevance of Australia in a changing world (Caldis, 2019).

The study of Geography in schools and at university requires students to increasingly develop their capacity to access, use and interpret, and communicate through a range of constantly emerging technologies related to datasets and GIS. Augmented reality sandboxes provide an example of how a technology-enabled teaching tool can be used to connect learning about terrain and topography (Geography) with atmospheric processes and climate (Science, Geography), soil attributes and crop yields (Science, Agriculture, Mathematics), and infrastructure considerations for a community (Engineering, Geography, Mathematics). Geospatial technologies allow students to show connections between subjects, demonstrate their holistic interpretations about place and spatial patterns, and make predictions about future environmental events.

The Federally-established Science and Research Priorities encourage users of GIS-related technologies and data to make connections between food, soil and water, transport, energy and resources, health, and population to develop innovative solutions to the so-called *wicked problems* of a connected world. Such technologies are currently being introduced for use in schools, within Geography classrooms and across STEM education projects. Therefore, a formalised statement where Geography also becomes recognised as a STEM education subject will promote the development of the so-called 21st Century skills or general capabilities. Understanding Geography to be within the key learning area of HASS, and as part of the STEM education repertoire, will allow educators and students to grasp what is both new and important for effective participation in, and contribution to, a rapidly changing and globally connected world. (Caldis, 2019; GTANSW-ACT, 2018; Kerski, 2015; National Committee for Geographical Sciences, 2018).

Despite all this, the continued importance of the humanities cannot be understated. The role of the humanities is, as outlined by Hay (2016), "to share and build on knowledge and to participate in a (scholarly) community in which knowledge is scrutinised and challenged relentlessly, constantly taking account of empirical revelations and conceptual rethinking". The humanities cast a light on the ideas and practices that shape the nature of the society in which we live. They allow us to better share experiences and gain an insight into the lived experience of others. They enrich lives by nurturing creativity. They make our lives more rewarding and enjoyable. They provide us with the skills that enable us to make meaning from all that is around us – skills that will hold us in good stead in an unpredictable future.

The humanities complement and nurture STEM in a variety of ways. They provide, for instance, an understanding of the context within which science gains its significance and from which it draws its authority (Hay, 2016). In a rapidly changing and technology-focused world, the humanities provide balance and perspective. They strengthen our worldview and broaden our intellectual foundations. They promote critical thinking skills and creativity, enhance our communication and problem-solving capacity, and contribute to the development of engaged citizens and thinkers (Reiter, 2017). It is within this broader educational context that Geography makes its own unique contribution.

Geography has the potential to make an important (and perhaps unique) contribution to both STEM and the humanities. It is the discipline that spans (and often integrates) the physical sciences, social sciences and the humanities. It emphasises spatial thinking and the creation of new knowledge via the study of places. It recognises the fundamental importance of the environment to human welfare and promotes an awareness of the interconnections between phenomena and processes both within places and across space. Places and people are increasingly interconnected globally, and society's challenges require answers that integrate different fields of knowledge. In a world in which inequalities within and between places can threaten social cohesion, and where the pressure of human impacts on the environment is a growing concern, Geography has much to offer.

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