SPOTLIGHT ON SCIENCE LEARNING

THE EVOLUTION OF STEM EDUCATION:

A Review of Recent International and Canadian Policy Recommendations

MISSION

Let's Talk Science is a national, charitable organization that motivates and empowers youth to fulfill their potential and prepare for their future careers and roles as citizens. Let's Talk Science supports learning and skill development using science, technology, engineering and mathematics (STEM).
Spotlight on Science Learning: The Evolution of STEM Education is the latest research report from Let's Talk Science, made possible by Amgen Canada.

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FORWARD

Technology defines our present reality and shapes our future prospects. Almost every day, we hear or read that the future of developed countries like Canada hinges on our ability to not only transition to, but become a leader of, an innovation-driven, technology-rich "knowledge economy".

Within this larger conversation, the role of primary and secondary education and, specifically, the importance of science, technology, engineering and mathematics (STEM) learning, are receiving increasing public attention. As a critical driver of this much discussed transition to a 21st century (and beyond) economy, STEM learning is being recognized as a priority – not only by governments but by parents and students, and by other stakeholders like industry and community organizations. It is increasingly clear that as the impact of technology continues to grow, the ability of individuals to participate meaningfully in all spheres of life will depend more heavily on the foundations of STEM learning and associated "competencies," including an understanding of scientific methods, numeracy, digital literacy and problem-solving.

The Canada 2067 backgrounder, of which this is a summary, grapples with some of the key questions facing those who wish to ensure that Canadian students have access to the kind of STEM learning they will need to succeed in the economies and societies of the 21st century – whether it be as innovators working on the cutting edge of technological advancement or as citizens participating fully in the life of their communities.

The analysis contained in this paper forms one part of a stage-setting exercise aimed at supporting and informing Canada 2067, an initiative of Let's Talk Science. This unique initiative aims to spark and convene conversations among Canadians for the purpose of developing a new vision for STEM learning in Canada. In researching this paper, it became clear that Canada's education systems are in enviable positions and that Canada has considerable expertise and success in education to share with others. Nonetheless, many of the challenges facing education in other countries are also present in Canada. By examining whether and how these challenges have been identified elsewhere, and the policy tools that are suggested as potential means of addressing them, this report hopes to provide useful contextual information and stimulating sparks for discussions in Canada.

ACKNOWLEDGEMENTS

Several academic experts read earlier drafts of the full report and provided extremely helpful comments during the research process. For these contributions, the authors thank Dr Julie Bélanger, Dr David Blades, Dr John Murray, Dr Jerine Pegg and Dr Dawn Wiseman. We appreciate you sharing your insights, expertise and time so generously. Your comments contributed greatly to shaping the paper and the companion, Canada 2067 Learning Framework. The authors would also like to thank Dr Bonnie Schmidt who commissioned this paper and provided extremely valuable comments and feedback at several critical moments. Naturally, any errors remain the sole responsibility of the authors.

EXECUTIVE SUMMARY

Societies are changing. The emergence of new technologies is disrupting how businesses operate and interact with their customers, how people work and the careers they pursue, and even how citizens relate to their governments. More than ever before, full participation in almost every sphere of life – from private and professional to political – depends on basic understandings of the principles of mathematics and science and how they are applied in the technologies that surround us. More and more, personal and national success depends on effective science, technology, engineering and mathematics (STEM) education.

Education stakeholders are asking both how well their STEM education systems are doing and what improvements are required. Indeed, the question of how education systems are advancing STEM learning has become a magnet for scrutiny worldwide as technological disruption reshapes the landscape of work and citizenship. Consequently, there is no shortage either of analyses of existing systems' shortcomings or recommendations for improvements.

This summary presents an overview of the full report, which aims to summarize these analyses and recommendations by reviewing over thirty policy reports focused on STEM education published in the last decade.

The reviewed reports are published in English and are focused mainly on STEM education at the primary and secondary levels in developed western countries in Europe, North America and Australia. Reports were selected for inclusion largely based their purpose, namely that they provided policy advice to governments, as well as on availability and accessibility, and the expertise and knowledge of the education policy literature possessed by the authors. Some additional reports were also included in response to suggestions from reviewers of earlier drafts of this report.

As a group, the reviewed reports give a wide variety of both international and Canadian perspectives on STEM education and its role in society as well as the policies and actions that will be needed as STEM education systems evolve. They include reports supported by a variety of intergovernmental organizations such as the Organization for Economic Cooperation and Development (OECD), organizations focused on particular STEM-intensive industries such as the Information and Communication Technology Council of Canada (ICTC), parliamentary committees, ad hoc expert groups, scientific bodies such as the Royal Society, and government education departments.

The international reports have been included to provide global perspectives on STEM education that frame Canada in a wider context particularly in comparison with peer countries. The Canadian reports focus on STEM education in Canada and provide insight into the more specific challenges and opportunities that characterize STEM learning in this country. The perspectives provided by these two sets of reports offer insight into the rapid changes currently underway in education and the growing attention to STEM that is emerging as an educational priority.

Critically, the report does not offer a review of the academic literature on STEM education but instead aims to provide a survey of the discussions that define the current policy landscape. Naturally, this landscape is connected with the academy; in fact, some of the reports reviewed here were written by academics with a deep knowledge of the academic literature on STEM education. Despite this important overlap, the policy landscape is distinct in its focus on recommendations to stakeholders such as governments, political parties and citizens. This report sets the stage and is intended to identify additional bridge-building and collaboration opportunities for policymakers and academics.

KEY AREAS OF CONSENSUS

The report has three main parts. The first part considers the nature of the current challenges facing STEM education and the extent to which a consensus is emerging on the best way to move forward. The second examines how these challenges can be addressed. The paper then summarizes key areas of consensus.

The focus in the first part is on three overarching themes identified during the review of the reports, including the need to:

1. **Increase the quantity and quality of graduates from STEM disciplines.**
2. **Broaden knowledge of STEM fields to better equip citizens to meet the demands placed on them in technologically advanced societies.**
3. **Refocus education systems away from the reproduction of set bodies of knowledge and towards the development of critical thinking, problem-solving skills and other related competencies among all members of society.**

While the implications of these three themes are often complementary, many of the individual reports tend to identify one of them as having primary importance, which in turn affects the focus of that report's policy recommendations.

Overall there are many important similarities across all reviewed reports despite obvious differences in educational contexts. This makes it possible to identify a number of areas of consensus regarding the key features believed to be important for the evolution of STEM learning.

Each of the studies reviewed was designed to respond to the circumstances of a particular country or region and its education system. What is striking, however, is not their differences but their many similarities. Naturally, the shared conviction that STEM education is a crucial factor in preparing employees and citizens to navigate a more knowledge- and technologically-intensive world is unsurprising. What is noteworthy are the recurring themes relating to the key challenges, and the similarity of the recommendations advanced. This makes it possible to identify areas of consensus regarding several key features of a more successful approach to STEM education.

1. HOW WE TEACH

The strongest consensus relates to the importance of teacher education and professional development. The concern is not that teachers are poorly educated, but that too many of those who teach math and science are not specifically educated in those disciplines and in the best ways to teach them. There is agreement that, to be successful, STEM education needs to be delivered by STEM specialists, even in the early years of education. There is also agreement that STEM teachers need to be provided with professional learning and development opportunities, and that these opportunities must be sustained and activate collaborative learning communities among teachers within and among schools.

2. WHAT WE LEARN

There is also agreement that STEM education needs to move away from emphasizing the transmission of set bodies of disciplinary knowledge and towards more multi-disciplinary inquiry-based approaches that support the development of specific competencies. Students' experience of science education should better resemble the processes of open-ended problem-solving and discovery that characterizes scientific practice. To that end, students should be provided with more inquiry-based, issues-focused and "real world" experiential learning opportunities.

3. HOW WE LEARN

The focus on developing competencies – the "what" of STEM learning (or learning outcomes) – can be supported by a modernization of the "how," that is, the pedagogy and the learning experience. There is a growing interest, for instance, in how STEM learning can be modernized in terms of both its integration of new creative technologies and techniques and its openness to creativity itself. This includes an increased focus on how to use ICTs, not just to teach competencies such as digital literacy but more generally to open up new possibilities in teaching and learning experiences.

Similarly, greater integration of interdisciplinarity into the curriculum is not only important in terms of broadening the subject focus of STEM but also in terms of enhancing the development of students' creativity and making the learning experience more engaging and inclusive.

4. WHERE EDUCATION LEADS

Concern was voiced in many studies over the lack of awareness among students and parents of the relevance of STEM to future education and employment opportunities. Successful STEM education systems are those that embed regular career education in the curriculum at all levels so as to improve students' – and parents' – understandings of the connection of STEM disciplines to a wide range of careers.

5. WHO'S INVOLVED

The successful delivery of STEM education is seen as requiring collaboration with a variety of partners, including the private sector, community organizations and especially parents. Collaboration between stakeholders has the potential to demonstrate to students the relevance of STEM education, inspire and support them in their pursuit of STEM-related studies and careers. It can enhance alignment of learning outcomes with the needs of the workplace. Partnerships can also be developed with community organizations, and with public agencies. Such partnerships can serve to expand the number and type of STEM learning opportunities and raise the profile of STEM knowledge and careers for students. By informing parents about the importance of STEM and how their kids are learning, these partnerships can also help to activate this key influence on students and their decision-making. Studies also noted the need for stronger leadership and coordination of these efforts, and improved horizontal collaboration among stakeholders, to ensure that these efforts receive adequate resources, that successful efforts are scaled-up, and that these efforts also help to strengthen the wider STEM culture within society.

6. CROSS-CUTTING ISSUES

Finally, there are also two cross-cutting recommendations best understood as woven through all of the issue-specific recommendations. The first focuses on paying particular attention to STEM learning in the early years of education, prior to when students begin specialized study of the separate STEM disciplines. The second is to address inequities in terms of participation and achievement in STEM education, including inequities between boys and girls, students from different socio-economic backgrounds, and Indigenous students and students from minority groups.

One area for which there is less consensus, however, concerns whether the improvement of STEM education should prioritize breadth or depth. For some, the need to increase the quantity and quality of STEM graduates pushes towards strengthening learning opportunities targeted at those already interested in STEM subjects to ensure that they are sufficiently engaged and challenged. For others, this "pipeline" approach is counterproductive, as it reinforces the impression that STEM is only for the gifted elite. From this perspective, it is better to focus on "STEM for all" by making STEM education more accessible. In an ideal world, both strategies can be pursued simultaneously without either interfering with the other. In practice, however, difficult choices must often be made in terms of curriculum (for example, whether to make STEM courses optional or compulsory) and the allocation of resources.

This tension returns us to the question of the precise challenge being tackled. The recommendations advanced in order to improve STEM education are intended to address one or more of three challenges facing education systems, namely how to: increase the number and quality of STEM graduates; improve the level of science literacy among all citizens; and promote the development of critical thinking and problem solving competencies. These three themes are not mutually exclusive, and can be seen as parts of a continuum. Ultimately, however, emphasis is often placed on one more than the others, leading to a prioritization of related recommendations, including the choice of whether to favour greater breadth or depth in STEM education.