in depth

Managing the Future: How can STEM education help?

by Sibel Erduran and Olga Ioannidou

CONTEMPORARY PROBLEMS AND STEM

The Covid-19 pandemic has reminded us of how much uncertainty surrounds us as individuals as well as societies. Little did we know even a year ago that our world would be engulfed in such a stark new reality that we are facing in our everyday lives today, ranging from wearing of masks to closures of schools and job losses. The pandemic has been teaching us a lot of lessons about coping with an international health emergency. Important new skills are emerging. For example, the ability to cope with uncertainty has become central to our lives. Furthermore, we have become dependent on information provided by health care professionals in order to make sense of our everyday actions. Should we wear a mask? Why should we be vaccinated? How should be socialise with other people in different spaces? Such questions have many elements of STEM knowledge embedded in them. STEM stands for science, technology, engineering and mathematics, and it has become a key educational goal across the world. How can STEM literacy help equip future citizens with skills to deal with uncertainty and other unknowns that the world might be facing in years to come? What are some potential problems facing our planet and society, and how can we educate the future generations to cope with such problems?

There are indeed numerous issues that have emerged in the world landscape in recent years apart from the pandemic that present new challenges to the content of the schooling system. Rising unemployment and economic difficulties have led to movement of populations placing demands on migrants to find new ways of coping with changing life situations. The climate change emergency is already posing significant challenges to ensuring that our planet is habitable in the not so distant future. What are the skills that future generations need in order to find jobs and to deal with the new societal challenges including a new job market? STEM education has the potential to equip learners with a range of skills to make sense of and to survive in the complex problem space of the future. STEM is inherently a cross-subject approach to investigating complex scientific problems with societal impact. Covid-19 pandemic is a representative example of such issues as it raises questions about the science of viruses, the technological innovation around vaccine design, the engineering of large-scale production of vaccines, and the mathematical modelling to predict the course of the pandemic. What is more, it raises moral questions about the way in which science and technology can be used to solve contemporary problems. So, the question that arises is: How can teaching and learning STEM help students navigate current and future societal challenges?

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STEM KNOWLEDGE

Understanding STEM problems requires students to be able to reason about STEM and have knowledge about how STEM works. Table 1 illustrates some aspects of knowledge and knowing in STEM and some potential questions that teachers can use in orchestrating classroom discussions and to orient the students to the importance of STEM.

THINKING AND REASONING SKILLS IN STEM

Apart from knowledge, STEM can impart students' particular *thinking* and *reasoning* skills. STEM implies skills such as creativity, problem-solving and critical thinking; skills which are all necessary to deal with ill-defined problems of the future. Furthermore, STEM knowledge is inherently inclusive of themes such as probabilistic reasoning and modelling that help us predict solutions in the future. Teaching and learning STEM subjects can also promote a so much currently needed evidence-based reasoning. All STEM fields rely on the use of evidence to sustain some claims. For example, we can justify why it's in our favour to have a vaccine against the Covid-19 virus based on the data on how it has reduced the rate of disease in people who have been vaccinated. When engineers produce prototypical models of bridges or factories, they argue for what makes the best design possible. If we are building a bridge in a gorge, we reason

ASPECT OF STEM	EXAMPLE QUESTIONS TO USE IN TEACHING
Why?	• What are the aims of STEM? • What kind of values guide STEM? • Are STEM professionals always objective? Why/why not?
How?	• What activities do STEM professionals use to collect data? • What kind of models are used in STEM? • How are models in STEM constructed from data?
What?	• What are theories, models and laws of STEM? • Are there differences between models in science and engineering? • How can we compare and contrast knowledge in different fields of STEM?

TABLE 1. Knowledge and knowing in STEM: potential questions for promoting discussions.

with evidence to confirm how the proposed construction will stay intact. Students' engagement in evidence-based reasoning may not only help with understanding how our knowledge in STEM is justified but also instill in students some trust about STEM. Across the world, we are increasingly witnessing much mistrust in science as illustrated by cases such as climate change denial, conspiracy theories about flat earth, the unsubstantiated 5G-Covid-19 which point to a whole array of misconceptions about how science works. In order to restore trust in students and more generally in the public, STEM education has to address misinformation about how science works and encourage understanding of how knowledge is validated in STEM. A coordinated approach to understanding the aims and values, processes and products of STEM is likely to help in restoring trust in STEM.

STEM, however, is not devoid of values and does not happen in a vacuum. It is situated in society and as such, the political, moral and ethical aspects of social factors can play into how STEM operates in society. For example, we have witnessed debates in some parts of the world whether or not vaccinations are against certain religious faiths and whether nor not places of worship should be open during the pandemic. In our *Oxford Argumentation in Religion and Science Project*, we have been tackling such issues through collaboration with secondary teachers[1].

Teaching and learning STEM subjects can also promote the much needed evidence-based reasoning.

STEM IN CURRICULA

How do current curricula address problems about STEM? In a recent study, we analysed science curriculum documents from the USA, Korea and Taiwan to investigate how these documents refer to the aims, values and practices of STEM[2]. The systematic study of these components provides information of how different curriculum standards compare and which particular features they emphasise. The findings illustrated that there is diversity in the way that epistemic aims, values and practices are discussed in these documents. Despite the structural differences among the documents, at least two important common themes were identified across the three countries. The first was the general underrepresentation of mathematics in the standards documents. What

distinct aims mathematics has that differ from those of empirical sciences, what practices mathematicians regularly engage in and how those practices help achieve the aims of science are very rarely addressed in the analysed documents. The second theme, particularly evident in the documents from the USA and Korea, was the overemphasis of science-engineering intersection, which seemed to have resulted in science-specific aims, values and practices being hidden in the standards. In both documents, the similarities between science and engineering were represented more evidently than their differences.

STEM AND THE FUTURE

Much work thus remains to be done to bring coherence to the curriculum about STEM. Furthermore, the curriculum can no longer afford to be indifferent to the needs of the future citizens. Students who will be future citizens need the knowledge, skills, attitudes and values that will help them in their lives in the years to come. How can teaching approaches facilitate the students to acquire such outcomes now? This is a key question that we are currently exploring in our partnership in the *FEDORA project*[3] led by University of Bologna, Italy. We are exploring some solutions to a serious gap of knowledge and skills that emerges from what the traditional educational organizations are producing and what the society requires. The overarching goals of FEDORA are to produce a new future-oriented approach to science education and to foster proactive and anticipatory policy making aimed to align science education. Future-scaffolding skills include scenario thinking, systems thinking, thinking beyond the realm of possibilities, action competence, managing uncertainty and complexity. The consortium involves three research groups in Science Education (University of Bologna, University of Oxford and University of Helsinki), a research group with expertise in

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sociological surveys from Kaunas Technological University (KTU), a company of science communication (formicablu) and the association *Teach the Future*. At University of Oxford, we are developing guidelines to renew science education. In particular, we are targeting science education researchers, teachers and other educators in formal, non-formal and informal contexts. We will compile policy makers' recommendations for future-oriented teaching and learning in schools. Ultimately, STEM education has much potential to equip students with the knowledge, skills and values that will help them cope with the emerging challenges in the global stage.

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Notes

[1] Erduran, S., Guilfoyle, L. & Park, W. (2020). Science and Religious Education Teachers' Views of Argumentation and Its Teaching. Research in Science Education. https://doi.org/10.1007/s11165-020-09966-2

[2] Park, W., Wu, J., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the United States, Korea and Taiwan: Focusing on disciplinary aims, values and practices, Science & Education. Science & Education 29(4), 899–927.

[3] https://cordis.europa.eu/project/id/872841