The Post-Pandemic Takeaways on STEM Literacy

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Abstract

The COVID-19 pandemic transformed the world at an unprecedented pace and still, to a lesser extent, is changing people's behaviours, decision making and lifestyle choices. Coping with the challenges of this transforming world and understanding the changes in people's daily lives has raised -or so it is widely argued- public awareness of the importance of STEM education and the impact that scientific literacy has on personal decision-making and action. This has brought on the 'STEM education for all' in the foreground in that there is a need for a STEM literate public to function and respond to the unprecedented amounts of scientific, mathematical (mostly statistical) and technical information exposed to during and post-pandemic. 'STEM education for all' can be thus defined as someone having "… the ability to engage with science related issues, and with the ideas of science, as a reflective citizen" [1, p. 22] which in the pandemic/post-pandemic era would imply a critical consumption of COVID-19 information and scientifically informed decisions by the non-scientist individual. Indeed, an understanding of, and engagement with, science can undeniably affect both public and personal decisions. However, a question that reasonably arises is how realistic it is for the average individual to have both breadth and depth of knowledge to a sufficient level to collect and analyse evidence and validate claims to then form rational and scientifically informed opinions on the science behind the COVID-19 or other contemporary issues like climate crisis [2]. This opinion-based paper draws on previous work [3] that questions the feasibility of 'STEM education for all' that would enable the non-scientist individual to make rational and evidence-based decisions about a broad range of socio-scientific issues. It is argued that this is both unrealistic and unachievable. However, the takeaways from the pandemic have highlighted the need for widespread, functional, and meaningful health and biology literacy with some coverage of chemistry and physics, and a greater focus in critical science literacy [5] for individuals, and for society as a whole, to engage sufficiently with STEM knowledge and how science operates. A more realistic approach to 'STEM education for all' with more appropriate and achievable goals could thus enable the individual to function in the society and form informed decisions on a number, yet limited in range, socio-scientific issues.

Keywords: *Science Literacy, STEM for All, COVID-19 Pandemic*

Introduction

The concept of 'STEM education for all' has gained prominence in the scientific and science education community [6], advocating for universal STEM literacy to empower citizens in making informed decisions. However, more recent dissenting voices [7,8] have questioned this shared belief various grounds. The COVID-19 pandemic has further prompted a rethinking and re-evaluation of the need for STEM literacy as per the extent to which preparing individuals to meaningfully engage with the science behind socio scientific issues, like a pandemic and climate crisis, is both realistic and achievable. This opinion-based paper critically examines the feasibility of achieving an all-encompassing STEM education that would enable the individual to navigate and respond to the dynamic challenges presented by socio-scientific issues and proposes a more pragmatic shift in focus to foster a more realistic and achievable 'STEM education for all'.

The role of, and need for, STEM education in preparing students to become STEM (with more emphasis on the Science subject as opposed to Technology, Engineering and Mathematics) literate citizens has been well argued in the literature [6] and embedded within curriculums across the globe in justifying why students should learn STEM on the one hand, and what the processes and products of such a STEM education should be on the other. For example, the framework for K-12 Science which includes primary and secondary education up to the age of 17-18 in the US states that [9 p.1] the goal is:

> [T]o ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science [the cultural argument]; possess sufficient knowledge of science and engineering to engage in public discussions on related issues [the democratic argument]; Are careful consumers of scientific and technological information related to their everyday lives [the utility argument]; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology [the economic argument].

The five key arguments that have been put forth to support the importance of STEM literacy have been questioned and challenged in previous work [7,2, 8]. In this paper, the focus is on STEM literacy in fostering informed decision-making in a way that would enable the individual to engage with STEM-related aspects of daily life (the utility argument) and civic participation in terms of meaningful participation in democratic processes and decision making in socio-scientific issues (the democratic argument). These two arguments align with the definition on 'STEM education for all' by the Organisation for Economic Co-operation and Development in that STEM education should enable the individual "…to engage with science related issues, and with the ideas of science, as a reflective citizen" [1, p. 22]

The 'STEM education for all' Utility Argument

The utility argument assumes that STEM literacy directly relates to and can be practically applied in everyday life and decision-making such as health-related decisions about nutrition, but the knowledge needed for health decisions would be more health and biology related which emphasises the need for biology and health literacy than STEM literacy or what an all subjects 'STEM education for all' would entail. Similarly, basic knowledge would help in making decisions about energy consumption and choices on the energy efficiency of household appliances but, again, this would be more physics/science literacy.

As discussed elsewhere [10] and the pandemic showed, a more comprehensive and meaningful approach is necessary for biology and public health literacy that would delve into the intricacies of biology, such as influenza virus biology and the impact of epidemics and pandemics on society. The focus should be on the basic, or as Nurse [11] put it, the "great" [p. 560], ideas of biology and how these can be applicable to every-day lives thus empowering informed decisions. This should encompass fundamental concepts such as immunology, epidemiology, and genetics to that level that would also equip individuals to engage responsibly with public health measures, like physical distancing during lockdowns and face covering.

Fostering health literacy would also enable the individual to find and make use of nutrition information for a healthy behaviour and actions. The focus should again be on an adequate understanding of basic mechanisms and concepts involved in daily activities like an understanding on water, muscle, and fat aspects and how they relate to nutrition and the importance of discipline in the diet and a healthy lifestyle for healthy living.

In a similar vein, mathematics education should prepare mathematics literate citizens to be in a position to use mathematical knowledge and tools "to utilize mathematics for solving problems in or describing aspects of specific extra-mathematical areas and situations, whether referring to other subjects or occupational contexts or to the actual or future everyday lives of students" [12, p. 43]. For instance, financial numeracy -i.e., knowledge and understanding of financial concepts and respective skills- would be practically useful in making effective decisions regarding the management of finance of the individual and their families. Similarly, an understanding of mathematical models as formulations that can (with some approximation) represent phenomena and situations could also be applicable in everyday life scenarios, thus enabling the individual to make decisions about a number of issues. An understanding of models regarding the climate change crisis, for example, and how people's daily practices relate to it, could be used in informing use of power practices, use of means of transport and food waste that all contribute to greenhouse gas emissions. Exponential models for virus contagion, and probability and statistics would, and have been proven to be during the pandemic, useful in taking the right measures to reduce the risk of catching COVID-19 and spread it to other people.

Revisiting the 'STEM education for all' utility argument

The pandemic has indeed added the need for functional STEM education for all that would promote necessary literacy levels for informed decision making in several everyday life situations. Hence, a knowledge of basic STEM concepts with an emphasis on biology, health and mathematics knowledge can be useful, but the entire spectrum of knowledge and its practical applications are often too specialized for the non-scientist individual to grasp without an in depth and extensive understanding and expertise. In other words, the assumption of the 'STEM education for all' in terms of its utilisation in everyday life oversimplifies the complexity of specialised STEM knowledge required for a number of issues on the one hand and its applicability by the lay person on the other.
While an understanding of the efficacy of the vaccine and the need to wear masks has been proven of particular importance and usability during lockdown, for example, an in depth-understanding of the SARS-Covid 19 influenza and the specificities of the modes of transmission, or an understanding of the epidemiological statistical evidence for a decision on wearing face masks, social distancing and vaccination would be both unrealistic and, as argued in this paper, not useful, at least not necessarily, to the lay person in their decision making to control the viral spread.
As the COVID-19 pandemic showed, contemporary scientific issues necessitate a response bringing together knowledge and expertise of highly qualified scientists from different disciplines that rarely collaborated so closely in the past and often disagree on the best measures to address these issues. Such responses require un understanding of multiple and often intertwined processes, interlinked outcomes, and a consideration of different scenarios. This raises the question as to what can be realistically achieved from a 'STEM education for all' so that the lay non-scientist individual to make everyday life decisions with a school-level STEM knowledge and when multiple process scenarios require specialism from different STEM areas to analyse and understand. Such processes are very common in the science behind the current socio-scientific issues like the climate crisis. Nevertheless, even STEM undergraduates struggle to analyse multiple process scenarios whereas the outcomes are often counteractive to the average individual-for example, an understanding of drought and floods as the results of anthropogenic processes is for many an 'either/or' phenomenon when essentially is an 'and' one in that both result from climate warming [13].

The 'STEM education for all' Democratic argument

The democratic argument suggests that 'STEM education for all' is a prerequisite for informed participation in democratic decision-making regarding socio-scientific issues. An example discussed elsewhere [20] is that knowledge of alternatives to fossil fuel power stations like wind farms and nuclear power stations and an understanding of the extent to which these can address the global climate crisis would enable the non-scientist individual to be able to engage in debate and decision-making at local and national level for their implementation.
In a similar vein, and as the Covid-19 pandemic showed, 'STEM education for all' should aim at equipping individuals with STEM knowledge that can be extended to the realm of the public health and societal impact of scientific contemporary issues like infectious diseases. Thus, STEM knowledge like the biology of Covid-19 and mathematical modelling for the consequences in terms of mortality and morbidity as well as economic ramifications, would ideally enable the individual to form an informed decision and engage in debates on measures to protect their communities during pandemics and proactive measures for future threads.

Revisiting the 'STEM education for all' Democratic Argument:

The democratic argument overlooks the depth of knowledge required and the ability to interpret this into applicable and actionable information for the lay, non-expert individual. The complexity of current socio-scientific issues requires specialised cross-disciplinary expertise, and this is when even highly qualified scientists from different fields may disagree on the effectiveness of nuclear or wind farms' power stations as an alternative to fuel fossil power stations to address the climate crisis, for example [2].
An education for such "wicked problems" - i.e., problems defined by high complexity, uncertainty and contested social and personal values [14] - would be both unrealistic and impossible. By this definition, the COVID-19 pandemic seemed 'extremely wicked' as the climate change crisis also is. Thus, a question that reasonably arises is what can realistically be expected of the non-scientist individual, with a 'STEM education for all' knowledge and understanding to look at these extremely wicked socio-

scientific issues and appreciate them from multiple perspectives to make scientifically rational informed opinions and engage in decision-making debates.

The argument for ‘Critical STEM education for all’

STEM is at its core a social endeavour and while heuristic/cue-based, processing is often regarded as inferior to systematic, more deliberate, processing the expert scientists are involved with in socio-scientific issues, it is undeniable that the lay individual relies heavily on such heuristics instead. Echoing Priest [15], this paper argues for a redefinition of ‘STEM education for all’ that would entail a comprehension of STEM knowledge as a social construct in that the scientific community collectively arrives at consensus (disagreement, research-based evidence, and derived conclusions through a rigorous process of open discussion, reassessment of knowledge and different scenario, peer review, etc.) is needed.
This shift in perspective necessitates a fundamental change in how non-scientist individuals are STEM-educated and how they approach STEM knowledge towards an understanding of science operationalisation within its social context. This includes comprehending the inherent uncertainty in scientific endeavours, the diverse specialisations within STEM disciplines and necessitation for a cross-disciplinary approach in addressing current socio scientific issues. More importantly this requires the recognition that science is inherently a social process that in most, if not in all, current socio scientific issues is imperfect, but, on the other hand, generate the best available knowledge. Critical STEM literacy should therefore encompass an understanding of the basic ideas in STEM but also an appreciation for the uncertainties and complexities involved, the influence of vested interests and discern, and trust expert consensus amidst diverse perspectives.

Conclusions

While acknowledging the undeniable impact of scientific understanding on public and personal decisions, it is contended in this paper that expecting individuals to attain both breadth and depth of knowledge sufficient for informed decisions across a spectrum of socio-scientific issues is both unrealistic and unattainable. 'STEM education for all' thus requires a more pragmatic approach, where both a broad understanding and appreciation for complexity is promoted. More importantly, a recognition of the limits of this broad knowledge and, due to the complexity of the socio-scientific issues, the need for trust in expert consensus needs to be understood and appreciated for the individual to be in a position to navigate and address these challenges.

What is needed for such a function of ‘STEM education for all’, which, as we argue in this paper, would mostly involve knowledge related to human health, biology, mathematics and some basic chemistry and physics, is to ascertain the core STEM ideas and concepts to teach, rather than necessitating depth of knowledge all four STEM subjects.It is also necessary to determine the educational level up to which these are to be taught in order to enable individuals to make rational, scientifically, informed choices and participate as citizens in the decision making of socio-scientific issues. In addition, *how to promote, model and scaffold an understanding of STEM knowledge as a social construct is required while research-based evidence that such a ‘STEM education for all’ would enable the non-scientist individuals to engage meaningfully with socio-scientific issues and contribute to address them is also necessary, in an attempt to promote a scientifically informed and engaged society.*

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