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Dialogues on Beauty Through STEM Education:
Graduate Student Special Issue
Guest Editor: Lydia E. Carol-Ann Burke
# JASTE 8.1: Dialogues on Beauty through STEM Education

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### Overview

JASTE is a journal for active promotion of social justice and environmental sustainability through science and technology education. This issue features a set of papers written by graduate students in response to an article about STEM education in JASTE 7.1 written by Dr. David Blades (U. Victoria) who, in turn, wrote a rejoinder to each student’s article. The Guest Editor of this issue, Dr. Carol-Ann Burke (U. Toronto), provides an introductory editorial and has written a final summary article here with Dr. Blades.

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EDITORIAL

Graduate Students Grapple with the Practicalities of Recovering Beauty through STEM Education

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to Dr. Burke at the above address. Thanks!

When I received an email from Larry Bencze (co-editor of this journal) advertising the JASTE Special Issue on STEM Education, I was keen to see how the activist interpretation of the science, technology, engineering and mathematics (STEM) construct might differ from that presented in a recent Special Issue in a subscription-based journal to which I had contributed (Shanahan, Burke & Francis, 2016). Having a keen interest in STEM developments across Canada, I scrolled through the pages of the JASTE Special Issue and before long my attention settled on David Blades’ Letter to a junior colleague (Blades, 2016). Since I had recently been speaking with David about my new faculty appointment in science education, I imagined (perhaps somewhat egotistically) that I was the intended audience for this publication. As I read, much of what was written resonated with some of the objectives I had for my own teacher education classes. Indeed, with David’s permission, for the last two years our program has been using an adaptation of one of his assignments to explore wonder and beauty in science with all of our elementary teacher candidate cohorts (see Blades, 2015 for David’s keynote address presented at the Canadian Science Education Research Group—SERG—Conference 2015). I began to wonder how applicable David’s proposals about STEM and beauty were to a teacher education context. An idea was formulating with regard to a graduate course I was developing titled Curriculum Issues in Science Education.

The course explores the historical and philosophical origins of the Ontario K-12 science curricula. It starts by examining the sociopolitical context within which the Science Council of Canada’s curriculum review of the late 1970s and early 1980s took place. Students examine a range of documents contributing to this review, contrasting them with contemporary scholarly texts and commentaries. The aim of the course was to contextualize Canadian and international debate on the direction of science education as students explored the question: How can an examination of the ways that science education has developed and been mobilized in different classroom contexts inform our focus for the future of science education? The course’s emphasis on using our examination of the past and present of science education to support us in making more informed choices about the future of science education aligned so well with David’s letter that the idea was birthed: as a culminating assignment, students would write a response to David’s open letter published in the JASTE Special Issue on STEM Education.

1 Editor’s Note: Larry had invited David Blades to contribute to the Special Issue of JASTE on STEM Education after having enjoyed his part in a role-play conference presentation (goo.gl/hS3Bn4) at the University of British Columbia (Blades, Weinstein, & Geason, 2014).

All students enrolled in the class (21 in total) were Master’s students. Some were in the final months of their Master of Teaching program (gaining teacher certification at the same time as a research-based master’s degree), others were experienced teachers returning to complete a coursework-based MEd, and still others were MEd students who had backgrounds in science but who did not have school-based teaching experience. This diversity of backgrounds supported development of a rich and diverse range of perspectives from which the students took up David’s letter. A selection of student response letters is included in this Special Issue and we are so pleased that David has agreed to write his own series of responses to the students’ ruminations: I know they will be delighted to have the conversation progressed in this way.

By way of orientation, the set of graduate student response letters begins with Mark Thomas’ account of STEM as a way of promoting integration of subjects to foreground issues-based education for a more responsive and responsible citizenship. Mark raises some provocative questions regarding the congruence of subjectivity, beauty, and science. In the second response letter, Sieran Yung reflects on personal experiences of science in both formal and informal educational settings. Sieran’s letter focuses on how we define beauty in STEM and explores how teacher modelling can inspire feelings of wonder in science students. Andrew Mannone writes his response letter from the perspective of an elementary preservice teacher. Andrew considers how some of the valuable messages from the Science Council of Canada’s review have retained their significance despite the rise in newer, shinier constructs such as STEM; his emphasis on citizenship education is illustrated by his exploration of science as a means of supporting development of 21st century competencies. The fourth contribution is made by Fraser Telford; Fraser speaks from the perspective of a history specialist likely to start his teaching career in a generalist elementary classroom. He highlights ways in which the combination of STEM and aesthetic appreciations provide him with a clearer pathway into science education. Zoya Padamsi’s response letter proposes resistance to STEM altogether, given that we already have a construct (STSE) that works very effectively in the Canadian sociopolitical climate and reinforces the ethical dimension of scientific practice. Our final contribution is made by Deanna Harris who demonstrates how her own research interests in science, technology, society and the environment (STSE) are influenced by the recent emphasis on STEM education and highlights how subversion may not be the means by which the place of STSE is reinforced in Canadian science education.

This small collection of responses provides a flavor of some of the conversations occurring amongst our next generation of science educators. I congratulate the students on their hard work during the course and hope that they will enjoy reading David’s individualized responses.

References


Dear Professor Blades,

I wanted to take this opportunity to respond to your open letter to a junior colleague on beauty in STEM education. I am new to this education game. As a (almost) newly graduated teacher, my perspective is neither as broad nor as deep as I am sure yours and other experts’ are. However, I do feel like my insights can provide a fresh set of eyes with which to look at things.

You spoke to a number of ideas that I agree with whole-heartedly, such as the merit of science, technology, society and environment (STSE) education, and ideas that I could potentially get on board with after a little more convincing, like infusing beauty into STEM education. However, I also felt you were somewhat dismissive of another topic that I believe warrants a little more air-time than it was afforded in your letter, that of STEAM and STREAM and whatever other acronym we would like to use illustrating an integrative approach to education.

I, like you, am a strong advocate of STSE education. I mean, why would we not “pump-out” globally responsible, scientifically- and media-literate citizens? Particularly if the alternative is having curriculum writers tailoring education to neoliberal agendas and pumping out the next generation of good little workers, as has been the suggested, albeit cynical, goal of STEM education. If I could have it my way, STSE would be THE science education. Science would be issues-based, and from those issues we would apply the principles of science, technology, society and the environment, just as the acronym implies. This approach would allow for an integration of subject areas that not only permits students to think from different perspectives, but encourages or even requires students to do so. I like integration. Why should every thing taught in schools be siloed off into its own individual world? Biology is not independent of chemistry, as even a surface level analysis of any biological system might reveal. How can one hope to write a lab report without language proficiency? How can one suggest a viable solution to the Keystone XL pipeline expansion dilemma without a consideration of the implications to the economy, environment, First Nations groups, and other socio-economic factors surrounding such a project? I like integration. Integration is good. So I do believe, that though the goals of such initiatives like STEM and STSE arguably vary in their merit, their core idea of integration has value.

That said, I think you are correct in saying that, despite arguments about STEM pushing a neoliberal agenda in an attempt to manipulate the education system, it is not going anywhere anytime soon. I like that you recognize that, and I like that you suggest that STEM could be used as a vehicle to undermine such market-driven ideas. However, I did not fully understand, or perhaps appreciate the argument for bringing beauty into the curriculum. I suppose my biggest problem with beauty is that it is simply so subjective, so individual. Is the saying not, “beauty is in the eye of the beholder”? While one may find Michelangelo’s painting on the ceiling of the Sistine Chapel breathtaking, awe-inspiring, and beautiful, another person might find it equally as gaudy, over-the-top, and ugly. I am sure both of those individuals have developed strong arguments for their respective positions. Who is right? I suppose, ultimately, it does not really matter. We are entitled to our own opinions; however, is that not the problem with beauty in STEM? Or did I just paint myself into a corner? Like the beauty of Michelangelo’s paintings, does it matter whether or not beauty in
STEM can be evaluated? I guess I do not really know, and I suppose that is where my struggle with this notion of yours begins. So as an alternative that returns to that idea of integration, I want to revisit STSE and the idea of STEAM, STREAM and so on.

I know, I know, at what point does adding more letters to an acronym stop becoming descriptive and helpful and start becoming simply ridiculous? This is a valid point. I mean, STREAM? STEAM? SMET? STEM? I get it. However, the essential idea is sound. For instance, if we could integrate STEM with Arts (A), imagine the potential! But first, let me make sure we are on the same page. Arts does not only mean painting, singing and drama. It also includes social studies, economics, history, FNMI perspectives and so on. Does that not play into exactly what I was talking about earlier in regards to STSE education? Integrating across these subject areas allows us to stick with the STEM mandate, while also paying homage to principles of STSE and the nature of science, regardless of how ridiculous the acronym may sound. What is more (and kind of exciting), it is a clever way to play double-agent with the market-driven agenda. On the one hand, we are STEM-ing up a storm as per the wishes of the free market. But on the other hand, we are teaching students the nature of science, broadening their perspectives and hopefully increasing the likelihood of scientific literacy for all students, rather than simply creating the next generation of scientists.

I have one last argument for the promotion of STEAM. It requires us to put ourselves in the shoes of a student who does not see themselves as a scientist, or perhaps a student who struggles with math, but also happens to be someone who loves social studies and is passionate about the environment. Imagine you are that student. You want to learn about the environment, how to help the environment and so on, but it is locked away in this STEM fortress surrounded by science, technology, engineering, and math—four things you are scared of. Why would you ever even consider going into that fortress when it is so clearly a hostile environment for you? Conversely, if you were to throw in an element of arts, all of a sudden things do not look so bleak. You like arts and history, and you like the environment; sure, math is scary, but at least you will be able take solace in the artistic part of the course and maybe you will gain a better, more enjoyable perspective of math and science. Even if you do not particularly enjoy the math and science components of the course, you have been exposed to the subjects, and that in itself is half the battle. By integrating across subject areas, we can access more people. We can get more people involved in science by opening it up and making it less scary. We also appease the neoliberal market gods because we have even more people going through the STEAM system, except this way they are emerging not only as people capable of working in a required field, but also as globally responsible and scientifically literate citizens with an appreciation for a wide array of perspectives.

As I am nearing the end of my response, I figure it is likely time to make my stand; that is, if you have not picked up on it already. I advocate for adopting a Canadian definition of STEM that has subject integration at its core. However, not just integration of the S, T, E, and M, but also the A. Let us teach science in the real-world context that science outside the classroom is indeed firmly situated within. To isolate science into its own box, or to place it on discipline-based pedestals is counter to what science truly is, and that, well that seems pretty darn foolish, if not damaging, to me.

I hope my ideas have provided some food for thought. If not, well, so it goes. I will continue dreaming about an integrated schooling experience with STSE or STEAM at the center. But I do hope that is not the case and that my fresh set of eyes, if nothing else, provided a different perspective on STEM and science education in the Canadian context.

Sincerely,

Mark G. Thomas
Dear Mark,

Thank you for the response to my “Letter to a Junior Colleague” paper. As you know, the format of letters means a rather abbreviated response that, by design, leaves many questions open and unaddressed. Your letter invites responses to some of these questions and so, in the spirit and continued form of a letter, I wish to offer what is a partial response to these questions.

I agree that in my letter my comment about “STEAM”—which adds “Art(s)” to the acronym was somewhat dismissive. The letter format did not provide enough room to adequately deal with the role of STEM and neither does the format of this response, but I will expand somewhat the point I raise. I have seen some examples of “STEAM” both in curriculum design and in classroom practice. In each case, the “arts” aspect of STEM strikes me as an addition to the STEM framework. The idea seems to be that by adding “Art” to STEM, the school curriculum is not entirely dominated by STEM. But this attempt at “balance”, to me, actually encourages science dominance in schools. If STEM is part of the general science/mathematics education, then STEM becomes an approach (albeit ill-defined) to this education. When one promotes STEAM, it seems to me a capitulation to the entire curriculum being STEM, with the necessary addition of “Arts.” My first question would be then: What about Literature? What about Social Studies/Civics/History? The usual response is that these are assumed subjects under “Arts”—but this raises the question why STEM is so articulated and not just assumed under “Science.” The point, I believe, is that “Arts” are added to an acronym as a “what about us” curriculum imperative, without sufficient theorizing about what such an addition actually means in curriculum design and practice.

Continuing somewhat on this topic, then, leads me to consider the “A” in STEAM as a point of integration of STEM in the form of beauty. As you articulate so well, the concept of beauty is complex and generally approached as subjective experience. However, beauty as a concept or idea is considered well in philosophy in the area of aesthetics. It is not clear at all that our perception of that which is beautiful is necessarily subjective. Beauty itself could be a property of the world, which makes beauty part of science and by extension engineering and technology. In fact, a review of the journals of scientists in the 19th century demonstrates that the idea of beauty was very much part of the descriptions of the natural world. In engineering, one also finds a concept of beauty-in-design, such as the example of the Eiffel Tower. I am not sure if the idea of beauty might provide a way of linking STEM fields but there may be some value in considering this possibility. For example, is “elegance” in mathematics a form of beauty? Can a technology, such as computer chips, be beautiful? Is beauty an important consideration when, for example, an engineer designs a bridge? How does thinking of beauty inform our thinking about science, technology, engineering and mathematics? The converse is also very important: When do STEM fields enter the “ugly.” Is ugliness the absence of beauty or just not enough beauty? Is beauty measured on a sliding scale? I am exploring these questions but it seems to me that STEM represents somewhat related fields and articulating some of the ontological links between these fields may also provide a way for us as teachers to help our students conceptualize the inter-relationships between these fields, both in ways of appreciation and also in critique.

Finally, I appreciated your comments that STSE is important as a dynamic. I agree completely that STSE as a conceptual imperative—that is, as science education for citizenship—not get lost in the rush to approach curriculum from the perspective of STEM. But this is precisely my point in my letter to my colleague: STEM has strong parallels
with the post-Sputnik reforms, which were entirely based on international competition and these reforms were ultimately counter-productive in encouraging young people towards STEM careers. I worry that STEM, as advocacy for jobs to grow Canadian competitiveness, is moving down the same trajectory. We need to study science education from the perspective of curriculum history and not repeat the same mistakes. While I see your argument that STEAM helps to move STEM away from a singular focus of the curriculum on STEM-related job preparation, I believe adding “A” to STEM will not diminish the force of the neoliberal impetus that animates STEM, but perhaps we can undermine this very agenda through aesthetics, and that would be a beautiful thing.

Sincerely,

David
What is Beauty in STEM, and How Can We Inspire This Feeling of Beauty in Students?

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Professor Blades,

What stood out most to me from your letter, was the question about what makes something beautiful. You talked about the beauty of architecture, such as the aesthetics of its shapes and structures. Then you raised an example of a line of pipes that may have a pleasing symmetry, but as the waste that can leak out from them can kill wildlife, they are also ugly. This latter example of the pipes, where their ugliness is due to how they harm the environment, made me think of a more general question: How do you define beauty in STEM? Beauty may initially be seen as the physical, about the shape and form. But it could equally be about its function and effects on people and the environment. For instance, if something greatly improves a person’s life, then I would consider that something beautiful. In this letter, I will explore some different types of beauty in STEM, give examples from my own experience, and conclude with a proposal on how to inspire the feeling of beauty in students when faced with topics in STEM.

For the type of beauty that comes from being able to improve someone’s life, I feel that the e-reader is a gorgeous invention. It is not only attractive in shape and design—at least in my eyes—it is also an immense help to me in my life. I do not live in a huge apartment, yet I am a voracious reader and never cease to buy new books. So, my Kindle is nothing short of a miracle: I can store hundreds of books on my Kindle that take up no physical space at all. Another blessing that my Kindle brings me, is that I can magnify the words in the book. This is truly wonderful, as my eyes are rather weak in stamina; larger text makes reading much more comfortable for me. There is moreover no backlight on e-readers, which makes the screen feel as natural and soothing as a paper page. In addition, e-readers save paper: I cannot imagine how many trees e-readers help to preserve. We also do not need to pay for shipping when buying e-books online. This is an incredible fact to me, because I order many Chinese books from Amazon.cn; my Kindle saves me from having to pay the exorbitant fees to ship from China to Canada. So, in my view, the invention of the e-reader with no backlight, is a definite beauty, and simply a stroke of genius.

I understand, however, that not everyone is as enthusiastic about e-readers as I am, and I do acknowledge the disadvantages. It can be inconvenient if the e-reader freezes or becomes slow for whatever reason. E-readers are more physically vulnerable than print books, so you have to be careful not to drop, bang, or spill any liquid on them. As well, e-readers cannot view diagrams, charts, tables, or graphs properly, unless the publisher of the e-book specially formatted the tables and figures for these e-readers. Nevertheless, despite all these drawbacks, I still adore e-readers, and already feel quite attached to my Kindle. Beautiful inventions may lead one to form emotional attachments to them.

Some other types of beauty in STEM that come to mind, are the beauty of mathematics and of biochemistry. I find biochemistry very exciting; I picture all those intricate, wobbling molecules in my head. This type of beauty is visual, but also tactile. I imagine the soft, supple, and smooth folding proteins and enzymes, even though I have no idea what they would feel like to my fingers in real life.

For mathematics, I have always found calculus rather beautiful in a mysterious way, and I feel a similar sentiment towards vectors. I truly love thinking about those visuo-spatial phenomena that you can use vectors to express, and
that you can use calculus to calculate their areas and volumes. I know that vectors, calculus, and what they can do may sound stale and boring to most people; yet, I feel charmed by the images, feelings, and sensations I experience when I think about or do calculus and vectors.

In a similar vein, I enjoy calculating things. I love numbers, quantities, and exactitudes. There is something beautiful about the very idea and process of doing calculations, even if that may sound very silly and incomprehensible to others. Still, I find the act of calculation enjoyable and sometimes even soothing; perhaps this feeling of tranquil pleasure is why I find calculations beautiful? Yet, that is not the complete answer: the very idea and image of calculating values is pleasing to me as well, for some enigmatic reason. Related to numerical manipulations, I recently met a new acquaintance who said that once, she felt so touched when she was doing factoring in math, that she started crying! I actually understand that. The subject and the process are so poignantly wonderful that they could make you cry.

Therefore, beauty can be a result of your love for that something. Some may say that the feeling of beauty can become confused with the feeling of love. Yet, for me personally, if I love something, it would automatically be beautiful to me. If I hate it, then I would find it hideous.

Now, what can we do after understanding some different types of beauty as explored above? How can we inspire students to appreciate the beauty in STEM? My opinion is that beauty is inherently subjective, so there is no forcing people to see things our way. As much as I like to be optimistic, I doubt that most students would find calculus or vectors as charming as I do: we all have different feelings about what appeals to us, after all. Yet, what we can do is to try to convey to our students, through some mode of communication, the beauty we experience. For instance, via writing a poem or a short prose passage on the emotions that a particular subject evokes in you, and reading the passage out loud in class. You can even recite the piece as a spoken word performance, infusing your enthusiasm and love into your words, eyes, facial expressions, and tone of voice.

Another way would be to paint, draw, or make a collage to represent the beauty feelings you get from that subject, issue, or topic in science. If we have the ability, we can compose a song to express these emotions. In short, we can use art to bring to life our passion for that thing we find beautiful. This idea reminds me of the acronym you mentioned, STEAM, where Art joins the merry crew of Science, Technology, Engineering, and Mathematics.

All this may sound extremely vague and even mystifying to you and many others, so I will give some concrete examples. Let us take the case of the beauty in biochemistry and cellular biology. A short poem could be:

Translucent, luscious globes
Flow through the ether
Harmony reigns for a while.
Supple, smooth proteins
Lace and thread and embrace
As they fold into their final forms.
A torrent of ions flashes through that little gate
Like a river where memories and secrets rush in and overwhelm your mind.

Of course, much better poets than I would have numerous critiques on the poem I have just written. But the point is to convey the fervor we feel, to help students see, for at least one moment, what we see. As for visual art, we could, for example, express the beauty we experience in calculus by using specific colors, lines, and shapes. I might wash the canvas with hues of orange and yellow, and draw some curving black lines with softly tapering ends, to begin my picture. With music, I can demonstrate how intellectually and emotionally beautiful nanotechnology is to me. The music notes would be in a minor key to fill the ears with a smooth, undulating melancholy that feels like a stream glistening under the moonlight—a flute would be ideal for creating this sentiment. Then, the music picks up into a major key and becomes so lively and cheerful, that it jumps with exhilaration and electrifying energy.

Skeptics to my proposal may see my suggestion as nothing more than an idealist's wayward fantasies, but I would argue that that viewpoint is too pessimistic. These artistic performances or displays do not have to take long; they can
just be worked in occasionally during some science lessons, to show students the inspiring beauty you feel. Reading out a poem or playing a song would only take a few minutes, and showing the class a piece of visual art you have created would not take long either. In fact, this approach may increase the interest of artistically-inclined students towards science.

Another critique of my proposal, is that not all teachers have the ability to express themselves artistically, nor do all students have the capacity to feel stirred by such performances. This is true, as different people have different styles of interpreting and experiencing the world. However, if not through art, teachers can use alternative ways of conveying the exquisite and the delightful in a subject or a topic in science. One such way could be to tell stories of science experiences they had that excited them. For instance, a zoology teacher could describe a particularly thrilling trip out in nature, when they observed a family of foxes from afar. Similarly, students who are less affected by art, may be moved by other forms of expression, like the above mentioned storytelling method, where the teacher communicates the excitement, joy, and beauty they feel towards a particular topic or phenomenon in science.

More evidence for my proposal comes from my personal life. Some friends have asked me where my interest in science (and thus the ability to see beauty in STEM) originated from. It is possible that it is partly inherited from my father, who adores science. Yet, he told me that none of his siblings or parents had ever been into science. My mother’s side of the family seems even more indifferent to science. Perhaps my interest was mostly nurture rather than nature, as observing my father’s passion for STEM subjects, especially science and technology, might have encouraged my enthusiasm to develop. If my love and sensitivity to the beauty in STEM indeed arose mostly from nurture, I would say that another major source of influence for me, was the popular science books I read.

Although there is some stigma against popular science books because they “cater to the public,” it is precisely because the authors need to engage the lay reader’s interest that authors need to write in an accessible, stimulating, and intriguing way. A few examples of popular science books I have read throughout the years, include: *Drive: The Surprising Truth About What Motivates Us* by Daniel Pink; *The Talent Code: Unlocking the Secret of Skill in Sports, Art, Music, Math, and Just About Everything Else* by Daniel Coyle; *Flow: The Psychology of Optimal Experience* by Mihaly Csikszentmihalyi; and *Learned Optimism: How to Change Your Mind and Your Life* by Martin Seligman. The titles might sound too “pop” and exaggerated to some, but the first two books were recommended by a psychology professor of mine, and the latter two books are landmark works by eminent researchers in the field of psychology. Thus, popular science books are not necessarily pseudo-science or mere entertainment as some may believe.

These popular science books are an inspiration to me on how to interest those who are not science-lovers to begin with. Through the authors’ use of accessible language, descriptions of phenomena, intriguing examples, ways of organizing information into narratives, and other methods, writers can communicate the beauty of science to the general public. The sheer commercial success of many popular science books, suggests that we can convey the wonder and beauty in science (and probably other STEM subjects) via storytelling, since authors need to write about their examples, theories, and findings in a way that is coherent, absorbing, and powerful, just like a gripping story. Effective storytelling in these books relies on the literary and linguistic arts too, as the author uses written words to captivate readers.

All in all, it is very useful and interesting to explore what beauty in STEM means to different people. To inspire in students this feeling of beauty, I propose that teachers communicate to the students via art, storytelling, or some other mode, the beautiful things they see and feel in certain science subjects and issues.

Yours sincerely,

Sieran Yung
Beauty Through STEM Rejoinder: Part II

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Sieran,

Thank you for your letter. Your response to my open letter to a junior colleague complements well the response I gave to Mark earlier in this Issue. In your letter you provide a useful example of how an e-reader can be beautiful, even with limitations of this technology. Your point that, “beautiful inventions may lead one to form emotional attachments to them” presents an important research agenda in the area of aesthetics. I have been working with beginning teachers who aspire to teach students in elementary schools. These teachers often lack a deep understanding of the nature of science. While this reality is well-researched, attempts to develop or encourage this understanding have been relatively unsuccessful. However, I have found that inviting these teacher candidates to consider the beauty of the natural world or, as you observe, technologies, leads to precisely this deep emotional connection as well as a clearer understanding of the nature of science. I share your view of molecules and also the idea that there is something beautiful about calculus, something elegant in the way calculus provides a way to make sense of movement, area, volume and other attempts to describe the world. In this way, mathematics can be seen as an extension of technology. I agree that there is something beautiful about doing a calculation, because as you move through the process you find out, you discover; often this discovery is an answer to a particular question. In this way, engaging in mathematics is in process the same as engaging in scientific exploration and both processes can be beautiful.

But, to me, the socio-cultural aspect of these processes also need to be considered. For example, there is a record of the discussions and calculations officials in Nazi Germany used to determine the most efficient way to exterminate Jews and others they considered “undesirables.” The solutions derived are eloquent but what they were doing was also very, very ugly. So, consideration of context seems to me to always be important when thinking about the nature of beauty.

Your letter ponders the subjectivity of beauty, a point raised also by Mark. While I agree that trying to force people to see beauty is problematic, I do believe that as teachers we can invite students to experience the beauty in all forms, from unfolding nature to working on mathematical theorems. We can share our personal experience of beauty and talk about why we, personally, find something or some process full of beauty, just as you point out in your wonderful example of reading a poem. I believe such sharing is not something to add to STEM lessons; my argument is that such aesthetic appreciation and experience lies at the very heart of STEM as a human experience. I do not share your view that not all teachers are able to express themselves aesthetically since I believe to be human is to experience aesthetics to various degrees. However, as teachers we are not encouraged to express our aesthetics experiences or perhaps to even think in terms of beauty—that is left often as part of our lives outside of our pedagogy. I believe your letter is a good argument for bringing our experience of beauty into our pedagogy of STEM. This will not be easy, but your letter points out some ways we might do this in our teaching. The next step would be to also consciously make beauty a foundation for a STEM curriculum.

Sincerely,

David
Making Science Education Accessible for All: Shifting Focus from Employment to Developing Creative, Socially-Conscious Citizens

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Professor Blades,

I would like to begin by thanking you for providing the historical context for the role that acronyms, such as STEM, have played in framing educators’ understandings of science education. I have not really put much thought into them during my teacher education because I have felt that they (e.g. STEM, STS and STSE) all represent a similar overall message: that science education is more meaningful when it is integrated with other curriculum areas and considered in relation to societal and environmental issues. After reading your letter (Blades, 2016), I feel that I now have a better appreciation for these acronyms with respect to how they inform us about how science education is thought about.

Throughout my teacher education, my fellow teacher candidates and I have been encouraged to think about topics such as the purpose of science education and what it means to think scientifically. These discussions always seem to be filled with ambiguity and no concrete definitions or answers. In your letter, you discussed how these guiding framework acronyms have changed throughout the years and how STEM is just the latest and most current (Blades, 2016). I have learned that these changes are significant because they are connected to whatever the dominant social, political, economic and/or environmental contexts are at a given time. Therefore, it appears that the purpose of science education is determined by those in positions of authority.

In your letter, you highlighted the political origins of STEM as a response to job market demands by government agencies (Blades, 2016). In the United States, it was a framework that was deemed essential for developing future scientists, engineers and technicians in order to stay competitive with other industrial nations. In terms of my future role as a science educator, I share your concern with this limited view of STEM’s purpose (for future employment). I think that this focus is problematic for several reasons. First, I do not believe that Canadians are all that concerned about national supremacy in the fields of science, engineering, and technology. I think that this stems (no pun intended) from the fact that science education does not place a strong emphasis on providing a Canadian context for students. Over thirty years ago, Page (1979) advocated that the science curriculum should place a greater emphasis on the history of Canadian science and scientists as well as science and technology-related problems in Canadian society. As a school student, the only Canadian science content I remember was the work of Banting and Best and a small note on the “Canadarm”. When we did discuss science and technology related issues, they were generally more global ones (e.g. access to clean water in less developed countries) as opposed to things happening “in our own backyard.”

Another major issue that I see with using STEM to develop future scientists, engineers and technicians is that it streamlines the focus of instruction to a select few students. I recognize the fact that not all students enjoy the subject of science, just as not all students like art, creative writing, math, etc. Teaching a science curriculum, designed to create future scientists and engineers, to a room of people not interested in those professions will only lead to boredom and disengagement. As you discussed in your letter, when lessons focused on covering and memorizing all of the content that scientists and engineers “should” know, the programs were boring. It ended up having the opposite effect and turned people away from science.

Not every student in the class will go on to have a career in science. In fact, we do not know what the future career of any student will be. However, every student will go on to be a citizen. In order to make the science
curriculum more accessible for all students, it seems it would be of greater benefit to tailor science education towards developing informed citizens who can respond to and make decisions regarding important political, environmental and social issues. As you have suggested, the focus of the science education curriculum should change from one on careers in science to one that helps develop more socially-conscious citizens. By adopting more of a science, technology, society and environment (STSE) approach, my aim will be to help students become more informed of Canadian-related science, technology and environmental issues.

Finally, another major problem with the idea of using STEM to prepare for future employment is that we do not know what new jobs, technology or social/environmental problems will exist in the future. Recently, you were part of an expert panel that was tasked with creating a consensus definition for the future of science education in Canada (Murray, 2016). As Risi (1982) argued, attempting to prepare students for when they graduate means trying to predict the future. We are trying to prepare students for an unknown. I believe it is in our best interest to help them develop skills and competencies (e.g. such as critical thinking) that are transferable and important for any informed citizen.

Ontario’s Ministry of Education (2016) clearly recognizes this in their new document, 21st Century Competencies: Towards Defining 21st Century Competencies for Ontario. According to the document, the main goal of the Ontario education system is to “enable students to develop the knowledge, skills, and characteristics that will lead them to become personally successful, economically productive, and actively engaged citizens” (Ministry of Education, 2016, p.3). The rapidly changing technology and social context of the 21st century means that people may have to collaborate to work and solve problems with peers both in the same room or halfway across the world (Ministry of Education, 2016). It is then critical for students to develop certain transferable competencies (e.g., critical thinking, communication, collaboration, creativity, and innovation) to be successful in these environments. I believe the 21st century competencies can be easily integrated into the science curriculum through either a STEM or STSE approach.

One of the 21st century competencies, the development of critical thinking, has long been considered a goal of science education. In your letter, you discussed how a deep understanding of science is needed by all citizens in order to make sense of the messages received from news media (Blades, 2016). Often scientific messages are taken out of context or blindly accepted without question. Munby (1982) shared your belief about the importance of developing an understanding of science, especially in relation to the development of critical (or scientific) thinking. He argued that an understanding of science is more than knowing how to conduct experiments. Science education should focus on helping students become aware that all scientific knowledge (i.e., theories, principles, concepts) are human inventions used to predict and make sense of the world around us (Munby, 1982). Munby also argued that the basis of critical thinking is being able to make judgements for oneself. In my future science classroom, I will attempt to foster this competency by constantly asking students about the usefulness of scientific information and various technologies. As you suggested, I will ask students questions like which groups are served by a particular technology or does a technology promote social justice? I will get them to reflect on their role in addressing environmental issues and the role they feel Canada should play in addressing political, social, economic and environmental issues of global concern.

Future science education curricula should also focus on developing the 21st century competencies of communication, creativity, and innovation. Thinking of these three competencies in relation to science education is also not new. To foster creativity and innovation, Risi (1982) argued that students should be taught to adopt the mindset of an “innovator”. This involves more than just coming up with new ideas. Innovation involves being able to manage, present and market your ideas, which makes verbal communication a critical skill (Risi, 1982). As part of science education, students should regularly be given the opportunity to discuss their thoughts and feelings on STEM or STSE issues and practice argumentation skills by using evidence to try to persuade others.

According to Risi (1982), innovators are able to effectively respond to a variety of information. In society, we have computers to store information. What will make students successful in the future will be their ability to take the information or knowledge that they have acquired, analyze it in terms of its usefulness and generate ideas for ways it could be used to address problems or issues. In order for students to develop creativity, they must be given the freedom to choose what they deem is the most appropriate method to solve a problem or complete a task (Risi, 1982). As a future science educator, this will mean allowing students the freedom for personal inquiry as opposed to having them just follow specific instructions. According to Risi, creative people are flexible when there is a divergence of opinion and they are able to adapt and move on when mistakes happen. In my future science classrooms, I will teach students that disagreement is alright in science and that it is how we choose to compromise and move forward that is important.
In support of shifting the focus of STEM from preparing students for employment, I agree with your argument of including discussions of beauty in science. I have learned that having these types of discussions with students (e.g., combining content acquisition with aesthetic appreciation) can help them develop both a greater understanding of science and a greater appreciation for it. Doing so communicates to the students that emotions and curiosity have a place in science education. These factors are important for engagement with the subject. They reinforce the fact that science concepts are complex human constructions.

When reading about your research with pre-service teachers (Blades, 2016), one thing that stood out was the idea that exploring beauty with the students promoted a stronger sense of responsibility and care for the aspect of nature being studied. This makes sense because it is human nature that we pay more attention to, and care more about, things that we like or find appealing. As I previously mentioned, as a student I often felt disconnected from the STEM issues we discussed. We were often occurring in other countries, so I felt distant from the problem. We were also predominantly bombarded with data, facts, charts, graphs, etc. If the teachers had placed a greater emphasis on beauty and the “human” elements of the issues, I probably would have been more engaged and felt a stronger connection to them. I also appreciated your discussion of technologies that are both beautiful in design and creativity and yet ugly because of the problems they create (e.g. pipelines bursting and oil spills). In the future, my discussions of technologies with students could begin with a focus on their “usefulness”. In addition to considering aesthetic properties, I could have them consider who serves to benefit from them and who or what (e.g., plants/animals) may be negatively impacted by them. I could then have them put on their “innovator” hats to brainstorm and present ways of addressing these STSE issues.

After learning about the continual shifts in thinking in the history of science education and through taking part in course discussions about science curriculum, I have gotten the sense that the purpose of science education is open. It is something that is dependent on the interpretation of the teacher and the needs of the students. In your letter, you discussed how curriculum is less of a product to be replicated in the classroom and more the dynamic interaction between teachers and students (Blades, 2016). I realize now that acronyms in science education are just guiding frameworks, not binding contracts. I may stray from these frameworks depending on how I perceive the needs of my particular students. I plan to answer your call to action by helping my students to develop a more holistic view of science. I will use your recommendation of changing the focus from careers in science and global competition to one of social awareness and cooperation. Along with the Ministry of Education’s 21st Century Competencies, I will use this philosophy to educate a future generation of informed, creative, innovative and socially-conscious citizens.

Sincerely,

Andrew Mannone

References


Dear Andrew,

Thank you for your letter. I am glad the historical narrative briefly introduced in my letter to a junior colleague resonated with you. I believe that history is important but also a sense of understanding of curriculum as a field itself. In my academic career, I’ve worked in curriculum studies to examine the issues around why educational change is so difficult; I have found that these often quite abstract curriculum speculations make the most sense when embedded in a concrete expression, which in my case is school science education. In the field of curriculum studies we argue that education is always a political act, so this begs the question: How is the development of an approach to science education, such as STEM, a political development? I find that those advancing STEM do so almost without consideration that STEM as an acronym has a history and force of ideas behind it; I believe that as science educators we should be aware of this history.

Does this history matter? You and I agree that it does. As you point out, the agenda of STEM seems to be an approach to education with the end-goal of producing more scientists, engineers, technicians and mathematicians. This goal is presented as somehow being self-evident; that is, the discourse of STEM simply assumes that Canada needs more employment in this area. We might take a cue from curriculum studies, though, and step back from this goal to ask, “Do we need employment in this area?” I completely agree with your point that STEM is essentially preparing students for an unknown future; you make an excellent point that education in general and science education in particular should encourage student’s thinking skills and competencies to help the next generation prepare for any future developments. STEM might be able to do this if the impetus for STEM education shifts to citizenship development. However, as you nicely observe, we already had such a shift in Canada. So, we might well wonder if an emphasis on STEM represents a shift away from science education for citizenship. I have also been inspired by Munby’s discussion paper; in fact, this paper was influential in my decision to leave my career as a high school teacher and become a professor (Glen Aikenhead’s paper in the same series also really influenced my thinking).

I love your phrase, “acronyms in science education are just guiding frameworks, not binding contracts” and it is encouraging for me at this place in my career to read that you, as a teacher, realize this. I believe such a view promotes teacher responsibility as interpreters of the curriculum. However, the reality exists that guiding frameworks quickly can become a form of entrapment into the ideologies that inform the framework. For example, with STEM it is not difficult to imagine Ministries of Education across Canada promoting STEM-careers and subsequently demanding that science teachers carry such promotion to their lesson plans. I’m all for students considering careers in the STEM fields, but this surely should not be the primary focus of a STEM-based education. This is where refocusing STEM on beauty can help to shift the impetus away from neoliberal agendas of competitiveness for its own sake, encouraging instead the deep understanding and appreciation of science, technology, engineering and mathematics that not only help to foster a more literate general public but also, I believe, will inspire students so that they will consider a career in STEM fields.

Andrew, I appreciate that you took my paper as a call to action that encourages 21st century competencies, that was my hope and intention as I wrote this paper-as-letter. I wish you every success in your quest.

Sincerely,

David
An Interdisciplinary Gaze Helps Us Better Understand the Creative Potential of STEM in Today’s Classrooms

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Professor Blades,

When I first read your letter; “Recovering Beauty Through STEM Science Education” I felt the message was pessimistic with regard to both the delivery of STEM programs as well as the programs themselves. I actually felt that you were in many ways fighting against its usage in the classroom. I am pleased to say that upon further readings I have found two important aspects of what you wrote that leave me feeling hopeful about STEM and its positive role for students. The first of these (which comes as great relief to me as a historian) is your use of historical context to explain the origins and current usage of STEM programs. The second is your desire to include aesthetics into the STEM framework as a means to break away from its more structured origins.

As a student at the Ontario Institute for Studies in Education (OISE) I have heard the term STEM used both at the university and during my school practicum placements. The shifting definitions of the practice that I heard over my two years mirrored much of what you described in regard to the difficulty of constructing a firm definition of what STEM is and what it is meant to be. What you provided in your letter, which I personally feel to be crucial in understanding the STEM construct, is some of the history prior to the development of STEM and STEM programs. STEM’s origins being in the 1970s and 1980s is not surprising but when one looks at what was happening prior to and during those decades it casts a very different light on what the original intentions were behind STEM teaching. Finding and developing scientists in order to compete at a global level was a Cold War mentality.

STEM has always played a different role here in Canada than in the United States. STEM was presented to me as a means of developing more integrated and student-centered programing. STEM seemed to be a way of better differentiating learning while creating a more inclusive environment in the science classroom. These factors could lead to getting more students interested and involved in science which is, from what I had been taught, largely what STEM was designed to do. Unfortunately, the STEM that I was taught about as theory was rarely what I saw put into practice. What I experienced was the more career focused teaching which you wrote about with a detectable level of disdain. Computer programing seemed to dominate many of the STEM programs which I witnessed as well as those described by my classmates. Repetition of previously perfected experiments had simply changed to the repetition of previously perfected STEM assignments. Rather than building on the student’s imagination and creativity much of what was presented was technical and instruction oriented.

With your explanation of the history of STEM’s origins, it is not surprising the way that it is primarily employed in today’s classrooms. The fact that all of the subject areas included in STEM require, similar academic strengths and skills restricts the inclusive abilities of teaching with this format. Grouping these subject areas together will quickly identify students with a predisposition for the sciences that is far from the presented goals of STEM. Identifying scientists and teaching based on the needs of current professions and careers may have worked during the Cold War but it does not seem to fit with present day attitudes. Change occurs at a rate where it is impossible to predict the skills required by our future work force. Teaching skills applicable to specific present day needs may actually be limiting to a student’s future options. Streamlining the instruction of specific skill sets could potentially produce a generation of students unprepared to meet the new demands presented in the coming years. I think that the history
you provided could be interpreted as putting a negative light on STEM but I think it helps the reader to understand what needs to be changed in order to better meet the demands and challenges of today and not from forty years ago.

I fully support your argument that the inclusion of aesthetics could be this vital ingredient. Here in Canada the goals of STEM were never to develop an army of scientists to combat the science of our enemies. Integrating aesthetics into the STEM program would better achieve Canada’s goals of the program (inclusion and engagement), while still maintaining what is becoming a long tradition of STEM teaching and programs. I really like how you felt that by working from within the original STEM framework one can make a few additions and alterations in order to work against rather than with its “neoliberal” influenced origins. Continuity is important for teachers and changing STEM into something different would be confusing as well as validating to those who have long ignored STEM as simply a fad. I think working within a well-established theoretical system will give your ideas the best chance of being successfully implemented.

The discussion centering on the Eiffel Tower is an example of taking something that is real that students can see. Even more dramatic would be being there, but iconic structures often feel closer than the actual geographic separation due to regular and long term visual exposure to the subject. Teaching both the science of the structure while discussing the visual aesthetics allows students to connect the science learned with its real world application. Not only do they better understand the physics behind the structure but they understand why it is appealing. Architecture relies heavily on math and science but there is an important visual and creative element which is lost in STEM if aesthetics are not openly discussed. Emotive connections are often not a great concern to science teachers but it is not difficult to see how their inclusion could help a broader range of students connect with the subject.

While you were discussing student reflections on aesthetics I began thinking that a student reflecting on the aesthetics of something is essentially them reflecting on their sensorial and emotive experience. Experiences are often more powerful than instruction. One of my OISE cohort’s first assignments was to reflect on our earliest memory of scientific wonder. This introduction to science education through an emotive portal was a formative experience. For many, science is a technical discipline which they tend to avoid. These individuals have effectively forgotten that science is essentially explaining the endless wonders of the world around them. Not surprisingly few of my classmates’ early moments of wonderment had anything to do with computer programing or any other career specific skill set; some aspect of life or natural science was a common theme. While growing up and throughout our lives we encounter life science in a far more experiential manner than chemistry or physics even though all three exist everywhere. It is not surprising that life sciences, for many, provide a deeper, more emotive connection to the material. The role life sciences play in developing a wonderment of science is well known and yet more often than not students are learning computer coding rather than inquiring about and in nature.

If you are comfortable with defining aesthetics as how we experience an event or a thing and how this experience makes us feel, than the experiential nature of life sciences would connect well with your idea to infuse aesthetics into STEM. Many architectural designs are inspired by nature and teachers could take a similar approach to what you demonstrated with the Eiffel Tower when teaching a whole variety of life science concepts. While students learn about the structures and functions that occur in the natural world they can also engage in their aesthetic appeal. This discussion can lead in a variety of directions such as why symmetry is appealing, Fibonacci numbers and their relationship to nature’s many forms and why some animals are more appealing to people than others and how that would affect our attitudes towards them are but a few examples. I envision this style of learning to produce free creative thinkers rather than have graduates coming from a career specific mold. Giving students a chance to include their own feelings in the science class would bring them closer to the subject matter. I feel this analysis of aesthetics would reconnect many students to their early moments of wonderment and could potentially attract students who had forgotten their interest in science earlier in life. Engaging a greater number of students into science while developing creativity and imagination in the way these future scientists and science contributors will think, is far more in line with the Canadian attitudes regarding the goals of STEM. What you describe in your letter could very well reshape the way STEM is used in classrooms while also moving it away from the goals of the past which inspired its original creation.

I am clearly a fan of your historical analysis of STEM. I found it helped clarify in my mind both the overall goals of STEM as well as some of the reasons why its definition and usage are so inconsistent. Your ideas regarding aesthetics made a great deal of sense to me as I finish my teacher education and enter the profession. I can certainly see how this would develop creativity in those already on a scientific path as well as help introduce some to a subject area they had either not considered or had previously considered to be foreboding. I hope you don’t mind the
connections I made to the life sciences. Life science instruction is a passion of my own and when reading your work I could not help but see how the aesthetics and my own ideas regarding life science instruction came together.

Where I would take issue with your letter is the negative tone that it seemed to deliver on my initial reading. Much as you demonstrated the importance of historical context, I feel that it is important to take into account the current climate in education when you write such a letter. With so much confusion regarding STEM there seem to be a great number of unapologetically positive or negative depictions of STEM. With so much that I would consider to be important information contained in your letter I would hate for readers to shy away from engaging with its content due to it feeling like one more negative report on STEM.

I thank you for your letter as it provides the reader a great deal to think about. I hope readers do not walk away with a negative first impression like I did and if they do they return to discover both the important lessons of the past as well as the hope you provide for the future teaching of STEM.

Regards,
Fraser Telford
Beauty Through STEM Rejoinder: Part IV

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Fraser,

Thank you for your letter in response to the letter I published. I will respond in kind in the form of a letter, acknowledging that letters are not a substitute for a full research paper so my responses may not be as helpful as you might desire.

What is absent from any published text is the tone intended by the author; in this way, publishing a paper is an act of “giving over” your voice to readers and thus a writer has to also give up ownership of interpretation. Your letter presents a good opportunity to extend and develop a conversation, which is almost never possible in normal publishing and I thank you for your honest and frank comments.

I confess, Fraser, that the tone of my paper does carry an element of pessimism. This is less of a negative attitude towards STEM as one of suspicion. Unless you were directly involved at the Ministry level in your province, STEM seems to have just arrived as a curriculum framework with little to no explanation as to the origins and ideology of this new acronym. As I pointed out in my letter to Andrew, education is always a political act. For example, we bring children to a place called, “school” and then organize their learning—their day and even their bodies—in certain, often precise, ways. But the point is that this approach has a history and ideology and alternatives exist (such as Dewey’s approach to education) to this pattern that we have inherited. The point of my paper was to remind junior colleagues that STEM also has a history and in most forms a very definite, neoliberal ideology.

You note well in your letter how you learned about an approach to STEM that promoted inclusivity and citizenship yet what you experienced in the classroom was the force of STEM for careers. This is precisely the same problem with the post-Sputnik reforms in science education. While you assume that this approach in the 1960s encouraged young people to be scientists, engineers (especially rocket scientists), etc., in fact the opposite occurred: post-secondary enrolment in sciences subsequently declined around the world, what some called the “drift from science” that occurred in the late 60s and 70s. I see direct parallels between “competing with the Soviets” in the 1960s and the emphasis on “international competition” today as a rationale for STEM, which invariably means competing with China and I worry that the career focus of STEM will produce the same effect.

There is nothing inherently wrong with healthy competition, of course and I also believe in promoting to young people opportunities for careers in STEM-related fields. What I am opposed to is the use of STEM as a form of social engineering that focuses attention on careers in the name of competition since such a focus moves science education away from the forms of science for all and citizenship education that were still in development. You make the same argument as Andrew in that we do not know the future, thus the skills we should consider in science education, perhaps via STEM, are those necessary to help our students live successfully in Canadian society and as world citizens.

STEM could be used to advance this citizenship focus, if we reconceptualize STEM along the same trajectories as STSE science education. It strikes me as somewhat ironic, though, that we have to adapt and rethink the new arrival to the curriculum directions already in place in most Canadian provinces. Again, one might ask: Where did STEM come from? We should also follow this question with another: Why are Canadian Ministries of Education embracing STEM as a curriculum organizer? I have to say that when I pose such questions the response, to be blunt, is along the lines that “everyone talks about STEM now.” This strikes me as a very poor reason for adopting, at a national level, a particular way of organizing school education.
I agree, Fraser, that at least in name, STEM is now here to stay; we have lost our window of opportunity to challenge STEM as an idea. However, as you note, we can change the rules of the adoption and this is where I believe aesthetics plays a key role. The Eiffel Tower does provide a good example, especially since Parisians hated this tower during construction. Discussing with students why there was so much public outcry reveals how thinking in a certain way (i.e., the skyline of Paris should not be interrupted by such a tower) can prevent us from seeing possibilities. But a case study such as this also reveals how people loved their city as it was, and this could stimulate important discussions with students about the nature of change and the importance of tradition. This case study also demonstrates that a particular engineering achievement is never socially neutral. The same is also true of technology—no technology is “neutral”; the mantra that technologies are “mere tools” was effectively (and in my view finally) dismantled by the philosopher Martin Heidegger in his important essay on technology The Question Concerning Technology. How might STEM change if the “T” in STEM was open to critique? Are there technologies that should not be developed? What examples of the unintended consequences of technology could be examined in schools? What all of these considerations raise is the key question: What are we really teaching? We cannot claim that, in the absence of STEM-related case studies of critique, we are not teaching politics since the very absence of such critique is itself political.

I share your fascination with the complexity of trying to figure out the idea of beauty. The discussion about this very topic in the philosophical branch of aesthetics has a long history. Your points about symmetry capture the attention of philosophers, who wonder why humans generally find symmetry to be beautiful. But just as I mentioned in my response to Sieran’s letter, the socio-political context of what we find to be beautiful also matters. I once visited the Nazi experimental death camp just outside the Bavarian town of Dachau and was immediately struck by the symmetrical arrangements of the many huts that housed inmates; it was almost beautiful in layout. This suggests that we must not ignore connections between beauty and ethics, although there is very little discussion that I can find about the relationship between ethics and aesthetics.

I agree with your final point that the introduction of my paper-as-letter could have been less negative. This is important advice to any writers: don’t turn away readers by being overly negative right away. I was likely carried away in my overall thinking as I wrote those opening lines and I appreciate your wise council to be a little more coy as one begins a paper: good advice.

Sincerely,

David
Why Pursue STEM When We Have STSE? A Canadian Perspective

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Professor Blades,

Thank you for taking the time to share your perspectives on the field of Science, Technology, Engineering and Mathematics (STEM). Having only recently started a graduate program at the Ontario Institute for Studies in Education (OISE) in Toronto, Canada, my knowledge of STEM is limited. However, in order to pursue a career as a curriculum developer in science education, I believe that I will require a thorough understanding of STEM, given the numerous STEM-driven initiatives that are being implemented in Canada. In this respect, the ideas that you have expressed in your letter not only allowed me to become more informed about STEM but they also prompted me to become critical about its place in science education.

My overall impression of your letter is exceedingly positive because, although you are critical about the neoliberal agenda of STEM, you have not denied the possibility of broadening its perspectives to include the notions of ethics and responsible citizenry. Within your description of STEM, you have included a few comparisons to Science, Technology, Society and Environment (STSE), which is an aspect of your letter that resonated with me. This stems from my experiences with the science curriculum documents in Ontario, where STSE is still the primary objective, despite the growing popularity of STEM. Therefore, I would like to take this opportunity to engage in a discussion with you about why I believe that our engagement with STEM may not be justified, since we already have STSE.

Although I am aware that STEM can have more than one definition, my current understanding is that STEM allows students to appreciate the interconnectedness between the four disciplines represented in the acronym and to connect their knowledge to real world applications. This interplay of subjects can provide students with a more holistic perspective of the field of science. Another acronym in science education that also aims to provide an interdisciplinary approach to science, and one that I have been able to study in comparatively more depth than STEM, is STSE. Although Mathematics and Engineering are not a part of the STSE acronym, I would argue that there are opportunities to explore these disciplines within the STSE objectives. For example, one of the STSE topics in the grade 10 Ontario science curriculum document is the use of vision sensors in food safety and this would require students to have an understanding of the mathematical basis of optics and the design or engineering aspects of vision sensors that allow them to identify harmful substances in food products (Ontario Ministry of Education, 2008). Taken together, I believe that STSE and STEM are similar in the knowledge and skills that they impart to students through their interdisciplinary approaches.

However, as you have described, there are differences in the underlying purpose of these two acronyms. STSE encourages students to consider the ethical, social and environmental impacts of scientific and technological advancements, in an effort to promote responsible citizenship. On the other hand, STEM encourages students to pursue careers in science, mathematics, technology and engineering, so as to further the country’s economic agenda that is rooted in scientific and technological innovation and dominance. I suspect that when the driving force behind education initiatives, such as STEM, lies in the achievement of a competitive advantage, it is possible that the notions of social justice and moral values are considered secondary, or worse, are completely omitted from the discussion. My suspicion was further strengthened by Steele, Brew and Beatty (2012) who mention that ethics do not seem to be a priority for the funders of STEM initiatives. In addition, you have mentioned that the dominance of STEM in science...
education suggests that it has overwhelmed or replaced STSE approaches; this causes me to be concerned about the eventual loss of STSE along with its ethical tenets. Therefore, given the similarities between the knowledge and skills imparted by STEM and STSE and the importance of providing a Canadian science education that develops citizens whose decisions about socio-scientific issues include a consideration of social, ethical and environmental notions, I question the need for engaging with STEM when we already have an ethically-sound version of STEM, which is STSE.

It has become apparent that my preference lies in advocating for STSE over STEM, given the absence of ethical considerations in STEM. Although you have expressed a similar preference in your letter, you have also suggested an alternative and creative way of approaching STEM that prompts educators to pay attention to the negative impacts of scientific and technological advancements. Your suggestion of infusing STEM with Nature of Science (NOS) perspectives by questioning the beauty of these advancements in a philosophical sense represents a more conscientious way of enacting STEM. However, NOS perspectives are the very tenets of STSE, which suggests that we already have a science education construct that is rooted in these perspectives. This, once again, brings into question the need to pursue STEM in the presence of STSE. Similarly, Steele et al. (2012) have expressed their concerns about the absence of ethical considerations from STEM approaches and have suggested a blend between STEM and STSE that would allow students to acquire STEM-related knowledge and skills within the ethical framework of STSE. Moreover, Blackley and Sheffield (2016) have suggested Environment and Ethics as possible alternatives for the Engineering component or ‘E’ in STEM education and have stressed the importance of these two alternatives in promoting responsible decision-making. A common theme within the above two studies is that the authors are attempting to change STEM by infusing it with notions of STSE, such as ethics and care for the environment. Therefore, this would ultimately lead us back to STSE, which prompts us to reflect on the need to create ethical versions of STEM, when we can continue to use STSE.

After reading your letter, I was eager to learn more about STEM within the Canadian context. This led me to DeCoito’s (2016) article, where the author has outlined a wide range of STEM-based initiatives in Canada that are being implemented by universities, non-profit organizations, public-private institutions and government agencies. The author has also mentioned that the Toronto District School Board (TDSB) provides and promotes STEM-based activities for students. However, the absence of STEM in the curriculum documents demonstrates that it has not officially made its way into the school system. In light of STEM’s growing popularity in Canada and the support it is receiving from school boards, I suspect that the inclusion of STEM in the curriculum documents will be considered by members of the Ministry of Education in discussions about curricular reforms. So far, I have presented my viewpoints on why I believe that we should not only question the need to engage with STEM but we should also question the need to create newer versions of STEM that are infused with ethical perspectives as this would ultimately lead us back to STSE. Therefore, for the moment, I would like to imagine myself as a part of the discussions on curricular reform, where I have expressed my disagreement with including STEM in the curriculum, given the presence of STSE, and I imagine that my viewpoints would be met with some criticism. For example, there may be concerns that the exclusion of STEM would lead to fewer students becoming scientists and engineers, which would cause Canada to fall behind in the race for innovation. In response to this concern, I would explain that even though the scientific knowledge provided by STEM and STSE are similar, neither construct guarantees that science students will pursue careers in STEM fields. However, unlike STEM, the scientific knowledge that is learnt through STSE is embedded in ethical and moral values. Therefore, even if students decide against science-related careers, a science education that is driven by STSE will at least prepare students to become responsible citizens, who will strive to make just decisions about socio-scientific issues.

In an effort to encourage other members of the research community to question the need for STEM in science education, I would like to borrow your strategy of using plays at a conference to examine the STEM discourse, which I found to be a creative and engaging (Weinstein, Blades, & Gleason, 2016). However, I would like to broaden Marie’s character, who plays the role of a STEM critic, by adding to her script the ideas that I have presented in this letter regarding STEM and STSE. By bringing together multiple experts from the fields of STEM and STSE, including yourself, I believe that the conference context would provide an opportunity to consider multiple viewpoints regarding the need to engage with STEM, given the presence of STSE.

That being said, it would be naïve of me to believe that such strategies would end in STSE regaining its dominance in science education and I would like to emphasize that this is not my goal. I do, however, believe that before choosing to promote new educational initiatives, it is necessary to compare them to older initiatives, in order to
truly comprehend the need for the new initiatives. You have rightfully mentioned, in a previous paper, that we should “disrupt the taken for granted belief that science education should be oriented toward STEM; we simply ask, “Why should it?”” (Weinstein et al., 2016, p. 209). Keeping the Canadian context in mind, my aim is to simply extend this question by rephrasing it as follows: “Why should it, when we already have STSE?”

Although I stand by my viewpoint of continuing to use STSE, instead of engaging with STEM, I acknowledge that the prominence of STEM in Canada and the emphasis on developing new STEM initiatives are undeniable. Therefore, STEM’s continuing influence on science education cannot be ignored. This has encouraged me to explore ways in which both approaches can exist harmoniously. Shanahan, Burke and Francis (2016) have provided a useful technique for accepting the place of STEM and incorporating it into science education without foregoing our existing loyalty to STSE education and its objectives of responsible citizenship. This technique involves using STEM as a boundary object, which accepts multiple interpretations of STEM and, consequently, helps to maintain the place of other educational priorities, such as STSE. This combination of STEM and STSE may be useful for responding to potential calls for the inclusion of STEM in curriculum documents.

Given my limited experience in the field of science education, I am eager to expand my knowledge of STEM and STSE by seeking your thoughts on the ideas that I have presented. I would like to thank you for taking the time to consider my perspectives on STEM.

Sincerely,

Zoya Padamsi

References


Beauty Through STEM Rejoinder: Part V

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Zoya,

Thank you for writing to me as a response to the letter I published. As someone interested in developing science curriculum, I hope that you will also study the field of curriculum. I find that many of the events in the history of science education make sense in the light of the expanded look at historical events in the field of curriculum studies. As I mention in my response to Andrew’s letter, education is always a political event, so even the act of developing a science curriculum has underlying assumptions and ideologies that are important to understand, especially if we are to learn from the mistakes of the past.

I am very sympathetic to your argument that we already have an approach to science education that is evolving and that addresses the needs of an educated citizenry in the 21st century. I agree as well that engineering, technology and mathematics are already part of an STSE approach, which does indeed beg the question as to why we even need to think in terms of STEM. I concur as well that issues of ethics, environmental responsibility and critical thinking, all essential features of an STSE approach, seem to be secondary considerations (if at all) in STEM. As I note in my response to Fraser, there is nothing wrong with being competitive or with encouraging students to consider STEM-related careers but there is a key problem when this agenda is the primary driving force behind curriculum development in a country.

Let me provide an example of how the career-focused STEM driver can play out. When Ministries of Education talk about the “competitive advantage” that STEM somehow can give us, we might ask, “against whom”? Now, usually the answer is: China. So, really STEM can be seen as a reaction to the ascendancy of China as a world power. In this way, STEM starts to sound very familiar in agenda and intent to the post-Sputnik reforms that wound up decreasing student interest in science! The reason for this, which I have written about, is obvious: a focus on the knowledge required to encourage career choices in these areas invariably becomes a focus on content mastery. This translates, for students, into a boring, socially-sterile pedagogy where content is divorced from their everyday lives and concerns. The alternative, as you so nicely point out, is what we already have in STSE approaches to science education. I loved how you made this point by showing that those concerned about STEM are trying to put ethical issues into STEM—essentially trying to make STEM into STSE! But there is another element here, as well. Why are we threatened by China? The answer I’ve seen is that, per capita, China graduates more engineers than Canada. To this we might be a bit cheeky and ask: So what? The point is vague. Are Chinese engineers somehow so undereducated that we feel the need to socially-engineer schools towards pushing these Chinese engineers out of the international market? Are we worried that Chinese inventions will make Canada somehow subservient to China? If you press the reasons for “international competitiveness” the rhetoric starts to sound very shallow and even xenophobic.

I agree that in the play that Matthew, Shannon and I wrote, Marie’s arguments could include your points about STSE and from my perspective, you could include these in the discussion presented in the play. Our play was presented at an international conference on STEM in education and it is telling that we were the only presenters with a critical voice on STEM as a curriculum organizer. What is needed are more voices asking deep questions about why we teach what we do and your response to my paper is one of these; I hope that you will continue to express your concerns not only through publications but at conferences and at Ministry of Education meetings.

Sincerely, David
Dear Professor Blades,

Thank you for taking the time to share your perspective on Science-Technology-Engineering-Mathematics (STEM) education in Canada. As a “junior colleague” and newly trained science teacher, I have to say that I certainly share many of your stated concerns about the matter. Like you, I am also critical of the influence of neoliberalism on Canadian science education. Indeed, I share your emphasis on Science-Technology-Society-Environment (STSE) as a potential antidote to these influences, as well. However, at the same time, I do not feel that these shared concerns necessarily indicate that STSE and STEM are discrete and mutually exclusive educational frameworks in Canada, nor do I think that it is fair to suggest that STEM has disproportionately contributed to the production of “another generation of uninvolved, unengaged, and uniformed citizens” (Zeilder, 2014, cited in Blades, 2016, p. 26). Further, I would also like to suggest that it may not be safe to assume that STSE, as it is communicated in mandated curricula and practiced in classrooms across Canada, is entirely immune to the influence of neoliberalism, an ideology that you claim is primarily responsible for “animating” STEM education, in particular (Blades, 2016, p. 23).

Firstly, while the similarities that you point to in your letter between post-Sputnik American science education reforms and the more recent STEM education movement are undeniable, I think it is worth noting their differences, as well. Importantly, unlike the American science education agendas of the Cold War era, it does not appear that the introduction of STEM education has encouraged students to move away from science-related careers, nor does it seem to have resulted in a similar “public drift from science” in Canada (Blades, 2016, p. 24). Indeed, according to recent work carried out by the Council of Canadian Academies (2014), Canada appears to have maintained a relatively strong “science culture” and was ranked 1st of 33 countries in terms of its levels of public engagement in science. Further, though low compared to other developed nations, the proportion of Canadian students graduating with post-secondary degrees in the sciences appears to have remained quite stable over the last 10 years, despite widespread declines in such measures elsewhere in the world. In addition, of those graduating from Canadian universities with doctorate degrees, over half were found to be emanating from faculties of science and engineering (Council of Canadian Academies, 2014). Interestingly, it appears that where the apparently strong Canadian science culture is breaking down is in terms Canadians’ (comparatively poor) understanding of basic scientific concepts – or the “content” of science – something that education agendas like STEM have been accused of being too reliant on. Regardless of these claims, however, even measures of factual science knowledge among adult Canadians have apparently improved since the late 1980s (Council of Canadian Academies, 2014). Importantly, with this collection of findings in mind, in contrast to the American post-Sputnik reform context, it seems that there is very little evidence to support the notion that STEM has led to any widespread societal disengagement from science in Canada.

Moreover, while I certainly agree with you that the competitive, job-driven approach to STEM education that has been identified in the US is fundamentally problematic, I do not feel that this perspective has been wholly or uniformly transplanted into the Canadian context. Indeed, in the Council of Canadian Academies’ (CCA) 2015 report on the state of STEM skills and economic productivity in Canada, it was determined that, while a long-term commitment to “STEM education” was desirable, the Canadian labour market does not appear to reflect any “current imbalance of STEM skills nationally” (Council of Canadian Academies, 2015, p. 76). As a result of this observation, it was determined by the Council that “a focus on very narrowly specialized STEM skills development to meet short-term labour market requirements may have little relevance for meeting long-term skill requirements” (Council of
Canadian Academies, 2015, p. 76). That is, because of the perceived relative health of Canada’s labour market, it was presumed that a concerted emphasis on the further development of STEM skills among Canadian workers would be unnecessary and short-sighted. As is evidenced by this conclusion, it appears that the basic presumption that an emphasis on STEM education is necessary in order to bolster the national labour market is generally absent from the Canadian context, even in largely economic treatments of the topic, such as the 2015 CCA report discussed above.

Indeed, this general perspective appears to be shared by others working in the area of STEM education, as well. As was expressed by Shanahan, Burke and Francis (2016), where the “rhetoric of global competitiveness and fear of national failure” has been found to be commonplace in post-Sputnik American science education reforms, similar Canadian reforms have largely been “driven by science education, science teaching, and scientific practice communities” and not by economic imperatives (p. 133). As a result of these disparate histories, it has been suggested that STEM likely has been mobilized for different purposes in the two countries. For Shanahan et al., in Canada, these purposes are apparently myriad, with STEM education taking on a variety of different meanings and intentions across a diversity of educational professionals and contexts. From this point of view, STEM might be considered more accurately as a “gathering point,” whereby collaboration between educators can be effectively facilitated, as opposed to a discrete and well-defined approach to science education (Shanahan et al., 2016, p. 134). That is not to say that political and economic concerns do not enter the STEM picture for some Canadian education researchers and educators, only that it appears that these concerns have not been allowed to dominate the national STEM discussion in Canada to the same extent as it has in the US.

Like STEM, STSE has also managed to escape strict definition. That is, regardless of the intent of explicit education reforms, educators have been found to harbor a variety of different motivations for taking an STSE-informed approach to science instruction in both Canada and the United States (Harris, 2017; Lee & Witz, 2009; Pedretti & Nazir, 2011). Moreover, these motivations appear to have little to do with the ideals espoused by science education reformers and STSE academics (Lee & Witz, 2009). As a result, like Canadian STEM education, STSE appears to be represented by a diversity of perspectives and approaches in practice. In fact, the definitions of STEM and STSE may be so permeable that science educators are not always able to distinguish them. For instance, in my own preliminary research on the experiences of seasoned senior science educators in Toronto with the implementation of Ontario’s STSE curriculum expectations, teachers were often found to conflate STEM and STSE, suggesting that they were not making any clear distinction between the two in practice (Harris, 2017). Indeed, in Canada, the overt influence of STSE on provincial curricula has long predated that of STEM, and thus it may be expected that, while the STEM acronym has been very successful (as you rightly point out in your letter), the general philosophy of STSE may still predominate and colour interpretations of STEM among Canadian educators.

The potential primacy of STSE over STEM is also supported by more recent evaluations of the future course of science education in Canada. For instance, in the recent report, Science Education in Canada to 2030 (which, as I understand it, you were involved in), it was determined that the proposed next step in Canadian science education (represented by yet another acronym – SSTEE – or Sustainability Science, Technology, Economy and Environment) would embody an historical continuity with “the Science, Technology, Society and the Environment (STSE) movement which was a uniquely Canadian contribution to science education internationally and has been at the foundation of curricula in Canada for three decades” (Murray, 2016, p. 29). The role of STEM in the future of Canadian science education, on the other hand, was not highly prioritized by the panel of education experts and stakeholders who were consulted in the preparation of the report. To be sure, this apparently widely preferred “return to STSE” stance on the future Canadian science education is well reflected in your own expressed predilection for STSE over STEM (Blades, 2016, p. 26), as well as the assertion made by Shanahan et al. (2016) that STSE could easily be “reinvigorated under the umbrella of STEM” (p. 137). Indeed, somewhat paradoxically, it appears to me that the STEM movement in Canadian education has been more instrumental in refining STSE than in defining STEM in any coherent way (or at least, so it seems in largely academic circles).

That being said, it is still possible that the precise opposite could be true. That is, the influence of neoliberalism might already be running through STSE education on the ground, thus making it more amenable to an already apparently neoliberal-bent STEM. Indeed, I think it would be a mistake to assume that this could not possibly be the case. Consider, for instance, the Ontario context. When exploring the province’s explicit STSE curriculum expectations, the individualist and consumerist tendencies that are characteristic of neoliberalism are quite evident in places. Indeed, the Anatomy of Animals unit of the grade 11 college biology course provides a good example of this. Here, the STSE expectation, E1.2, requires students to “analyze the impact of various lifestyle choices on human
health and body systems,” suggesting an emphasis on the role of individual choice (often related to the consumption of goods and services) in the determination of health (Ontario Ministry of Education, 2008, p. 70). However, a more collectivist approach to this same concern might instead consider how systems of power and privilege have influenced the relative ease or difficulty with which certain choices are made by particular groups within society. For instance, the ability to make “healthy” lifestyle decisions easily might be mediated by issues of class, race, gender, physical/mental ability, and proximity to things like good grocery stores, green spaces, and health care facilities, and may not, as the curriculum expectation suggests, simply be a matter of personal will. That being said, the degree to which neoliberal perspectives have woven their way through existing STSE curricula is largely unknown (and probably worth investigating in the future). In any case, my point here is to suggest that STSE is not necessarily immune to such things, and thus might be expected to be open to the same extra-curricular influences to which STEM is susceptible.

Taken together, these considerations might indicate that STEM is not necessarily in need of active subversion, but rather, implies that subversive threads likely already exist within the STEM education discourse in Canada. That is not to say that neoliberalism does not permeate science education, including both STEM and STSE, in general, however. As you have suggested (and I agree), it appears that the best course of action in order to deter the influence of neoliberalism in science education might not be to police the use of the acronyms that guide it, but rather, to remain committed to a prolonged conversation about their content and meanings, both in theory and in practice, as you have done with the publication of your letter on the subject.

With sincere thanks and admiration from a “junior” colleague to a “senior” one, I hope that my input on this matter has been well-received and serves to generate still further debate on this increasingly important topic in Canadian science education.

Best,

Deanna Harris

References


Beauty Through STEM Rejoinder: Part VI

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the author of this paper. Thanks!

Dear Deanna,

Thank you for your articulate and insightful response to my open letter. In my opinion, you correctly point out that the neoliberal forces animating STEM (at least, the original reason that this acronym emerged) also affect STSE. I agree, but there is an important difference. In STSE approaches, neoliberalism is an unwelcome influence, something that STSE works against in the “society” form of STSE, while with STEM neoliberalism is the fundamental ideology. Whether this ideology contributes to a generation of disenfranchised youth remains to be seen, but the potential is there.

The statistics you cite are quite recent so a historical perspective is in order; in the decades immediately following the post-Sputnik reforms, Canada experienced a spike in enrolments in post-secondary science education, followed by a dramatic decline. The reasons for the decline are quite clear: we imported wholly, and without change, the science education programmes developed in the USA. These American programmes caused a drift from science that was felt in Canada; a study of the now defunct Science Council of Canada declared in 1984 that Canadian science education was in a state of “crisis.” This crisis was that young people in droves were not considering science-related careers, among other issues. I was teaching secondary school science at this time and the Science Council convened a series of discussion papers; two of these (one by Munby and the other by Aikenhead) really affected me. Both papers argued for a new approach to science education in our country, one more along the lines of STSE. The STS movement was forming in Europe and Canada also adopted a leadership role in designing STSE curriculum. The result was an increase in student enrolment, so the statistics you note relate to the way Canada responded to the crisis. My concern is that STEM could take us in directions opposite to the hard-fought gains of the past 3 decades.

I also agree that the uptake of STEM in the USA is not the same as how STEM is being adopted in Canada. This is because Canada has, for the past 30 years or so, deliberately adopted approaches to science education that do not replicate American approaches. This ethos seems to pervade the country now and while we certainly do look south of our border for ideas, we also look East and West. The result is a long practice of innovation and adaption of ideas from other countries and we should expect the same for STEM. In fact, my work with Ministries of Education involved us looking at curriculum developments in Australia, Denmark and a host of other countries. In one remarkable meeting where we were looking at designing a new science curriculum for a province, American examples were completely absent.

The fact that there is not any real demand in Canada to increase STEM careers begs the question: Why STEM? As Zoya points out well, in Canada STEM seems to be adopted with infusions of social issues, ethical responsibility, etc.—in other words, STEM is being reformed into what appears to be STSE science education. However, even though this seems to be the case, I believe STEM is here to stay.

You make an excellent point that STSE has eluded clarity, although a significant effort was made in the pan-Canadian framework for science education presented and developed by the Council of Ministers of Canada. This document, dated now, clarifies STSE and adopts an STSE approach to science education curriculum development. Alas, our very provincial approach to curriculum development prevented anything like a national uptake of this formative document and so each province was left to make sense of STSE, with the resulting confusion and variation. As you say, STSE has escaped definition and this may be one reason why STEM is so popular—the acronym is, for the most part, simple to remember and catchy.
I was indeed involved in Murray’s study; in his survey he discovered a justified pride in the contribution Canada has made to the world in the development of socially-responsible school science education. For those of us who made this part of our life work, to see STEM essentially take over is somewhat heartbreaking. However, you make a solid and encouraging point that in Canada we will likely adapt STEM into a form of STSE; I wish I could share your optimism. We educators will most certainly need to be vigilant; my time as a formally-employed academic is nearing completion, which is why I wrote this paper-as-letter to those newly entering the field, such as you.

Sincerely,

David
Giving STEM a Context: The Beauty of STEM(S)

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Responses

JASTE is a non-refereed, open-source, journal. We encourage reader feedback on contributions to it. Please send your comments, suggestions, etc. about this paper to the authors of this paper. Thanks!

Reflecting on the process of compiling this Special Issue, we see how the journey has provided us with a rare opportunity to make public the initial articulations, critical feedback, and eventual refinement of ideas about science, technology, engineering and mathematics (STEM) and the role of beauty in science teacher education. It is almost as if we are still in conversation with the authors of the various letters; in this sense, the conversation lives on. We start our final reflection by commending the authors for the depth of thought, care, and insight demonstrated in their well-crafted responses; we will attempt the same as we draw together and re-examine some of the central themes that have emerged in these exchanges.

In our opinion, the search for a depoliticized science education agenda is neither realistic nor desirable. If we can agree that all education is inherently political then the blind adoption of any initiative without the commensurate reflection on the political nature of the adoption can be risky. While we acknowledge the rapid, and perhaps uninvited, integration of the STEM construct into Canadian education discourse, we recognize that, as science educators and researchers in Canada, we cannot afford to ignore the neoliberal driver of national competitiveness that has formed, framed, and continues to attend the STEM acronym for our neighbors in the United States. In retrospect, it might have been somewhat misguided to suggest that “STEM is an acronym in search of a meaning” (Burke & Bazzul, 2016, p. 572) as this gives the impression of a benign term that is awaiting definition. We prefer the interpretation presented by Mannone in this Issue where he states that, “acronyms in science education are just guiding frameworks, not binding contracts.” In agreement, we assert that, as a community of researchers and educators, we have a responsibility to examine what STEM, and its sociopolitical trappings, might, could, or should mean in the context of science teacher education and K-12 science classrooms in Canada. This deconstruction and re-theorization could help to redirect the trajectory of this fast-paced object.

In Canada, the majority of secondary school students do not go on to pursue STEM-related careers but every student can utilize science literacy today and in their future to critically engage with societal issues that arise from developments in science, from technological innovation, from approaches to engineering, and from applications of mathematics. Young people need to understand STEM and the impacts of STEM on their lives and the lives of others. School science is the place to develop this critical literacy and this is why, in the face of inevitable STEM, we...
suggest Canadian teachers place societal concerns and issues at the centre of any approach to STEM education: STEM(S).

One way to help students understand the interconnections between the various parts of STEM and their societal contexts was suggested in the paper that stimulated this Issue (Blades, 2016): exploring the beauty in science. Alongside the ethical dimensions of science that STSE demands we examine, we see the potential for an integrative/interdisciplinary STEM approach to be used as a means of recapturing the long-neglected beauty of science. It is not a far stretch to see how the creativity aspects of STEM design processes could support the return to an area of science that the natural philosophers and scientists of the 18th and 19th centuries captured so well; indeed, in this Issue, Yung has eloquently and persuasively drawn on the aesthetic facets of science as ways of developing a student’s depth of connection with the field of science. The concept of beauty as a foundation for studies in STEM goes beyond the integration of arts into STEM—the so-called STEAM approach. We argue that simply adding some aspect of the arts to STEM, as an additional element as is often the case with STEAM, does not go far enough in truly integrating the different facets of the acronym.

We envision beauty as a more foundational approach to STEM. As argued in the various conversations, beauty is complex and difficult. We believe that this is the strength of this concept: the difficulty in deciding what is “full of beauty” and what is not. Imagine, for example, discussions by students about the aesthetics of an engineering design. What is appealing? In what ways are the social effects of a particular creation by engineers beautiful? Beauty weaves through mathematics in the form of elegance, introducing students to the philosophy of mathematics. We might explore the beauty of a technology and ask if this technology also has possible effects on society that we find ugly. Such discussions reveal to students the deep, human nature of STEM, removing from activity in STEM any sense that STEM is somehow socially neutral. Beauty is complicated precisely because beauty calls us to the societal aspects of STEM education. Bringing beauty to the science classroom represents a returning to the history of STEM. For example, the introduction of the technology of coal-fired steam trains in England brought tremendous controversy as people found the noisy, smoke-belching train technology greatly depreciated the beauty of the countryside. Students could benefit from an examination of the controversy surrounding the introduction of such technologies, for we continue to introduce new technologies today and anticipating how these technologies can and might be adopted in society is one way to be engaged in the social order as a citizen. Examining the example of the trains even more, we might find that the organization of pistons, wheels, cogs, and hoses forms a network that is beautiful in design and symmetry, providing another facet for examining the STEM of trains. This illustration shows that the possibilities are endless when STEM topics are linked through a foundation of beauty that invites, questions, and critiques STEM in science education, driving us back to the challenges and subjectivities of social context that underlie science education in our country.

The history of science reveals how scientists shared their rapture of the natural world. The diaries of the women and men who surveyed mountains, studied newly discovered elements or saw microbes for the first time, speak of the beauty of the world. What did they mean when they said that the world is beautiful? Have we lost this aesthetic sense in science education? If so, can we recover this sense through beauty in STEM? Would such instruction bring students closer to an authentic experience of science in the way that professional and amateur scientists experience science? We can imagine astronomers sharing with students what first inspired them to study the night sky or a geologist describing when they first fell in love with rocks. We argue that bringing beauty to STEM would likely provide similar inspiration, and perhaps even more students would consider a career in a STEM-related field. Our hope is that those who enter STEM fields do so because they are inspired or have fallen in love with one or more areas in STEM but for those who do not, we hope that beauty encourages and fosters the critical literacy towards STEM topics so very much needed to inform and direct the decisions that students face today and in their futures.

References