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Abstract

STEAM education is intended to integrate a creative and aesthetic dimension into STEM education. By drawing on John Dewey's philosophy of aesthetic experience and by exploring a simple mathematical problem (Is the graph of a given function increasing at a given point?), I argue that STEM education already has an aesthetic dimension inherent within it. Furthermore, I argue that by recognizing this dimension of STEM curricula, STEM teachers will more easily be able to facilitate aesthetic experiences for their students.

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Keywords

Aesthetics, Mathematics, Dewey

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The STEAM Inherent in STEM: A Mathematical Example

Aaron S. Zimmerman

Introduction

STEAM education is intended to integrate a creative and aesthetic dimension into STEM education (Bequette & Bequette, 2012; Radziwill, Benton, & Moellers, 2015; Rufo, 2013; Sotiropoulou-Zormpala, 2012). In this essay, I argue that STEM education already has an aesthetic dimension inherent within it. Furthermore, I argue that by recognizing this dimension of STEM curricula, STEM teachers will more easily be able to facilitate aesthetic experiences for their students.

Dewey (1934) argued that aesthetic experiences are not isolated to formal works of art (e.g., painting, sculpture, music) but are a fundamental part of everyday human experience. As Sinclair (2009) writes,

In Dewey's conception, the aesthetic does not describe the qualities of perceptual artifacts; rather, it characterizes experiences that are satisfactory...Aesthetic experiences can be had while appreciating art, while fixing a car, while having dinner, or while solving a mathematics problem. They are aesthetic in that they combine emotion, satisfaction and understanding. (p. 50)

Dewey advocated for understanding "the aesthetic as a continuous, unifying quality that underlies experiences – not as a separate mode of judgment exercised after inquiry is complete" (Sinclair, 2009, p. 50). That is to say, problems are *felt* before they are thought or formally stated in rational terms. There is, according to Dewey, a *qualitative* dimension to all inquiry (including scientific and mathematical inquiry). Therefore, I

argue that problem solving within the context of the STEM curriculum involves not only formal reasoning but also aesthetic experiences.

A Mathematical Example

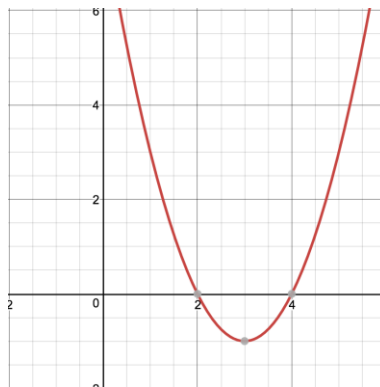
This paper will present a close reading of a mathematics problem that might be found in a Pre-calculus mathematics course. This problem is, in many ways, rudimentary, but I argue that it highlights the ways in which a STEM curriculum may present opportunities for aesthetic engagement. Consider the following mathematical function and the following question:

$$f(x) = (x - 2)(x - 4)$$

Is the graph increasing at $x = 4$?

Although this question is fairly straightforward and conventional (suitable for an Algebra 2, Pre-calculus, or Calculus curriculum), I argue that answering this question in a satisfactory and comprehensive manner requires aesthetic discernment.

The first issue with which we must wrestle is what it means to be “increasing”? One very rudimentary definition could be stated as “the graph is going up.” Let us, therefore look at the graph of this function.



Yes, the graph is “going up” at $x = 4$. But what exactly do we mean by going up? The graph gives us a visual representation, but can we translate this visual representation into a mathematical representation?

The following is one attempt: Assume that we have points x_2 and x_1 , where $x_2 > x_1$. We might say that the function is increasing on a given interval if $f(x_2) - f(x_1)$ is always greater than zero.

Can we prove this in our example? Yes: We could actually tabulate values, such as $f(4.1) - f(4.0)$, $f(4.0) - f(3.9)$, $f(4.02) - f(4.01)$, etc. We would find that, indeed, all of these values are greater than zero.

Therefore, we now have three different representations of the term “increasing”: a graphical representation, a formal, logical representation, and a numerical representation.

This now brings us to a second question: Can a graph or a function be increasing *at a single point*? Note that the problem does not ask us if the function is increasing between $x = 3$ and $x = 4$. The graph is asking us if the function is increasing *at* $x = 4$?

I want to explore two separate arguments: The first argument is that the question cannot be answered. After all, we defined the term “increasing” as the difference between two values (e.g., “going up” from one point to another point). If we are considering only *one* point, the concept “increasing” loses its meaning.

The second argument is to look at the numerical examples $f(4.1) - f(4.0)$, $f(4.0) - f(3.9)$, and $f(4.02) - f(4.01)$. What might happen if I keep performing this procedure, tabulating values, but letting x_1 and x_2 be closer and closer together. For example, I could compute $f(4.000000002) - f(4.000000001)$, and a convincing argument could be made

that, more or less, I am numerically exploring whether or not the function is increasing at $x = 4$ (i.e., right around the area of $x = 4$).

Indeed, I can express this argument mathematically in the following way:

$$\lim_{\Delta x \rightarrow 0} (f(x + \Delta x) - f(x))$$

In other words, I am letting the difference between x_1 and x_2 be as small as possible (i.e., the difference between these values approaches zero), and then I am computing the difference between $f(x_2)$ and $f(x_1)$, right around the point $x = 4$. If this value is greater than zero, then I could argue that the function is increasing *at* $x = 4$.

The Aesthetic within STEM

The point of the above mathematical exploration was to show that a deceptively simple question (such as, “Is this function increasing at a given point?”) is actually quite complex. Furthermore, in order to devise and justify a solution to the above problem, the problem solver must not only apply logic but also follow his or her intuition. For example, what definition of the concept of “increasing” do we *feel* is sufficient? Does “going up” *feel* like a sufficient definition? If not, we may be motivated to use mathematics to go further and to refine this definition. In sum, it is the *aesthetic* experience (the affective encounter with the curriculum) that motivates the student to engage further in the mathematical thinking. As Dewey might say, it is the aesthetic, affective encounter with this mathematics problem that fuels the student’s trajectory of educational growth. The aesthetic, according to Dewey, *motivates* inquiry. Thus, I argue that appreciating the aesthetic dimension of science and mathematics is not an upshot of scientific and mathematical inquiry but, rather, is a catalyst inherent within the STEM

curriculum. All STEM curricula are replete with opportunities for aesthetic experiences. It is the responsibility of the teacher to recognize such opportunities.

Many novice teachers are apprehensive about teaching art and integrating art into their curricula, given that they do not inherently view themselves as artists (Oreck, 2004). If teachers are able to recognize the aesthetic dimensions already inherent within their STEM curriculum, then this may improve teachers' inclination to recognize and to highlight the aesthetic dimensions of scientific and mathematical inquiry. As teachers increasingly recognize these dimensions, students will increasingly be afforded opportunities to experience the aesthetic within the STEM classroom.

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