The Politics of Aesthetics of Mathematical Coherence: STEM Students' Aesthetic Interpretations of Cross-Curricular Stories

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As part of a larger participatory, arts-based study, six STEM students engaged in sustained arts creation and reflection across their curricular experiences as a form of holistic, multimodal, and multisensory aesthetic critique of their cross-curricular mathematical experiences. In this contributed report, I detail instances where students' perspectives on curricular coherence (i.e., their aesthetics of coherence) deviated from privileged forms of disciplinary (logico-rational) coherence in mathematics education. In doing so, I highlight the exclusionary politics of aesthetics that result from a narrow adherence to one perspective of curricular coherence and the epistemic harm this can inflict on students in relation to how they position themselves as learners and doers of mathematics. These examples suggest a need for additional criticality concerning our often-unquestioned definitions of curricular coherence and acknowledgement that mathematical coherence seeking is governed by both aesthetic and logical forces.

Keywords: Curricular coherence, Student perspectives, Aesthetics, Arts-Based research

A common educational assumption is that curricular coherence is a pre-requisite for a "good" curriculum. Buchmann and Floden (1992), for instance, touted coherence as one of the "guardian angels of [curriculum] reform" (p. 4). In mathematics education, this perspective has persisted both nationally and internationally. For example, the recent ICMI study of mathematics curriculum reforms around the world puts coherence on a pedestal as one of the organizing themes for reform, with the final report stating matter-of-factly that "Coherence is likely to be a universal aspiration" (Morony, 2023, p. 148).

While curricular coherence is often unquestioningly accepted as desirable for student learning, some researchers have urged caution, arguing that "curricular coherence" is loosely defined with no widespread agreement over its meaning (Muller, 2022; Thompson, 2008). Canrinus (2024), for example, likened curricular coherence to a "disco ball" (p. 258) with several distinct forms and conceptualizations. Buchmann and Floden (1992) went further, referring to curricular coherence as a "rebel angel" escaping singular definition given that "coherence allows for many kinds of connectedness, encompassing logic but also associations of ideas and feeling, intimations and resemblance, conflicts and tension, previsagements and imaginative leaps" (p. 4). Indeed, the polysemous nature of "coherence" is reflected in its etymological origin, the Latin word *coharere*, meaning "to stick together" (Kolln, 1999). In other words, a "coherent whole" is one in which its parts are perceived as sticking together—or being related—in a satisfactory way. The upshot is that judgements of coherence involve a *holistic interpretation* of an object (curricular, artistic, or otherwise) formed based on one's aesthetic sensibilities and preferences for structural logics (Aschenbrenner, 1985; Repp, 2017).

For this reason, research on curricular coherence and designing coherent curricula in practice requires the consideration of multiple stakeholder interpretations of coherence (Bateman et al., 2009; Modeste et al., 2023). The perspectives of education researchers, disciplinary experts, and to a lesser degree teachers and administers have been investigated; however, outside of mathematics teacher education (Nguyen & Munter, 2024), *students'* perspectives on curricular coherence have only been peripherally considered. One result is that *disciplinary* forms of

curricular coherence have become the de facto status quo for curricular coherence in mathematics education (Cuoco & McCallum, 2018; Morony, 2023). From these perspectives, a coherent curriculum is one that consists of "a sequence of topics and performances that are logical and reflect, where appropriate, the sequential or hierarchical nature of the disciplinary content from which the subject matter derives", which requires that the particulars should evolve to "deeper structures inherent to the discipline" (Schmidt et al., 2002, p. 9).

These interpretations of curricular coherence reify a particular choice of mathematical aesthetics. As famed mathematician Henri Poincaré remarked:

> Mathematics is the art of giving the same name to different things . . . when language is well chosen, we are astonished to learn that all the proofs made for a certain object apply immediately to many new objects; there is nothing to change, not even the words, since the names have become the same. (1908/2012, p. 375)

Benis-Sinaceur (2014) called this form of generalization *idealization*, which involves "leaving aside or discarding all other aspects" thereby "extracting a *form* from sundry situations" (p. 94, emphasis in original). Disciplinary forms of coherence mirror this so-called art of idealization, privileging an aesthetic of "FUGS" (that primarily spotlights practices of Formalizing, Unifying, Generalizing, and Simplifying, see Hausberger, 2017, p. 418). Greeno (1992) has called this a "thinking-with-basic" philosophy in the sense that all concepts are seen as building hierarchically from the "basics". But what is "ideal" for some is not "ideal" for all. Not even mathematicians universally endorse such a limited form of aesthetics (Hausberger, 2017)!

Indeed, Sikorski & Hammer (2017) argued that there is a danger in a strict reliance on premeditated, expert interpretations of curricular coherence, suggesting that we must also consider students' idiosyncratic, in-the-moment coherence seeking in its many forms. Premeditated coherence, they argued, often undermines and undervalues the active role students play while seeking coherence: "sequences that attempt to guide students through a series of investigations to arrive at the canonically accepted (and 'coherent') explanation may do so at the risk of students' own epistemic agency in deciding what coherence to seek next" (p. 935).

Most importantly, there are grave ethical implications of privileging a singular, narrow view of curricular coherence. Buchmann and Floden (1991) observed that curricular coherence often has evaluative overtones which associate "coherence" with other aesthetic notions often viewed as universally positive, like "harmony" and "wholeness". They concluded that any perspective on curricular coherence required critical examination before being taken for granted as an inherent good. In other words, interpretations about what is "coherent" are fundamentally value-laden carrying with them (implicit) assumptions about the nature of learning and what "make sense" (Shemmer, 2012). As such, Richmond et al. (2019) argue that we must always question, "Coherence for whom? According to whom? To what end(s)?" (p. 188). Without such criticality, well-intentioned efforts to design curricula that is coherent from one perspective may inadvertently convey harmful messages about students who interpret these curricula as *in*coherent—i.e., that these students are *themselves* "incoherent," "bad," "not smart," "do not make sense", etc. (see e.g., Appelbaum, 2010).

In this participatory, arts-based study, I investigated the ethical implications when students' perspectives of curricular coherence and their aesthetics of coherence clashed with entrenched forms of disciplinary coherence. Six student-artists participated in sustained individual and collective arts creation and reflection across their curricular experiences with the goal of fostering "conspiratorial conversations" (Barone, 2000, 2008) on the topic of curricular coherence. An aim of these critical conversations was to destabilize privileged politics of

aesthetics underlying disciplinary coherence by drawing attention to a multiplicity of students' aesthetic sensibilities of coherence through the generation of aesthetically and emotionally impactful artistic educational critique (Barone & Eisner, 2012). In this contributed report, I focus on two research questions: (RQ1) What interpretations of coherence did these STEM students express that deviated from disciplinary forms of curricular coherence? (RQ2) What ethical implications did students' alternative aesthetics of coherence have on how they positioned themselves as learners and doers of mathematics?

Curriculum as a Storied Artform

I conceptualize curriculum as a form of art (Eisner, 2004) in the sense its content and *aesthetic form* cannot be disentangled, meaning that aesthetics cannot be ignored in curricular analysis. Specifically, I adopt the perspective that the mathematics curriculum can be metaphorically conceptualized as a *storied* artform (Dietiker, 2015b). As mathematics curricula enculturate students into the discipline of mathematics (Brown, 2022; Plut & Pesic, 2003), the stories they tell—and the *ways* these stories are told—should not be an afterthought. Indeed, the holistic form and structure of a story interpreted as a kind of narrative conveys disciplinary-cultural aesthetic, ethical, and onto-epistemological values about learning, living, and being (Stephens & McCallum, 1998). Following Dietiker's (2013, 2015a) curriculum-as-story metaphor, I take a reader-oriented perspective on narrative interpretation based on literary theory (Bal, 2017). From this point of view, meaning is not contained in the text itself but instead developed through a transactional process as the reader engages hermeneutically with the text (Rosenblatt, 1988; Weinberg & Wiesner, 2011). Through this active reading, *the plot*—a reader's aesthetic reactions to the unfolding of the story—is constructed based on their holistic interpretation of all story elements (e.g., characters, settings, themes) coordinated with their reactions to how the story events unfold. Importantly, the plot is constructed through both *logical* and *aesthetic* sense-making as a reader engages with (curricular) stories (Richman et al., 2019). From this reader-oriented point of view, curricular coherence is *not* an objective property of the curriculum itself but rather an idiosyncratic interpretation of (in)coherence a student makes while actively engaging with curricular stories.

The upshot of this theoretical framing of curriculum is that students' aesthetic sensibilities influence their curricular engagement and therefore learning of mathematics (Wong, 2007) as they construct subjective personal meanings and conclusions (Sinclair, 2005) concerning the (in)coherence of said curricular stories. In other words, one's personal aesthetics are fundamentally intertwined with how they make sense of the world and learn mathematics. By "aesthetics" I do not just mean judgements of beauty but rather "knowledge acquired through sensory perception" (Marini, 2021, p. 40), in line with its original etymological meaning where epistemology, aesthetics, emotion, and sense-making are inseparable (e.g., Dietiker et al., 2023). From this perspective, aesthetic experience (Dewey, 1934/2005) is an idiosyncratic response a person has to a particular object or event (e.g., a cross-curricular story), which could be positive (joy, wonderment, curiosity), negative (disgust, boredom, disappointment), neutral, or an eclectic mix of all these. Such aesthetic responses have been shown to play several roles in both professional mathematicians' and students' mathematical activity (Burton, 2004; Sinclair, 2004). For example, wonderment, surprise, and curiosity have been repeatedly linked to sustained engagement with mathematical inquiry (Dietiker & Richman, 2021; Gadanidis et al., 2016). Aesthetic considerations have also been shown to influence the nature of one's mathematical inquiry, including the questions one deems as (un)interesting and (not) "worthy" of further consideration (Fiori & Selling, 2016; Jasien & Horn, 2022).

Personal aesthetics are not developed within a vacuum but in relation to the *intersubjective* aesthetic sensibilities of the socio-cultural contexts individuals inhabit (Chilton et al., 2015; Conrad & Beck, 2015). Rancière (2000/2004) argued that which aesthetics become privileged within a community of practice (e.g., the discipline of mathematics) is political insofar as shared aesthetic practices result in distributions of what is considered sensible, often in ways that are covert. Consequently, aesthetic sensibilities (e.g., privileged views of curricular coherence) that are dominant within a socio-cultural context (e.g., the mathematics classroom) have a powerful influence on not only an individual's personal aesthetics but also how one's personal aesthetics are perceived (by the individual *and* others from within the socio-cultural context) (de Freitas & Sinclair, 2014). In this way, intersubjective aesthetics becomes a yardstick against which all other aesthetic sensibilities are measured and judged: privileged socio-cultural aesthetic sensibilities become a way of policing who/what is considered "aesthetic" and who/what is not.

Students' Perspectives on Curriculum in RUME

Research in undergraduate mathematics education displays many of the same general trends I detailed earlier concerning (a) a mostly unquestioned privileging of disciplinary forms of curricular coherence (e.g., Tague & Czocher, 2016) and (b) a dearth of curriculum research that centers students' holistic judgements about the holistic curriculum. There are a small number of studies that attend to the idiosyncratic ways students' engage with curricular stories at the grain size of a single course or lecture (Andrà, 2013; Krupnik et al., 2018; Weinberg et al., 2014) or, more broadly, to students' interests and what they value *across* their mathematics courses (Asada et al., in press; Leyva et al., 2022), but much less attention has been paid to students' general (aesthetic) perceptions of the undergraduate mathematics curriculum. One exception is a small handful of studies investigating mathematics *graduates'* retroactive reflections on whether their curricular experiences prepared them for their careers (King et al., 2017; Wood, 2010).

Participants and Methodology

This contributed report is based on a larger arts-based study (Tyburski, 2024) where I recruited six undergraduate STEM students from various disciplines who had just successfully completed multivariable calculus. Students were recruited from different STEM disciplines to spotlight a variety of (disciplinary) aesthetic sensibilities and promote the sharing of a multiplicity of perspectives of curricular coherence across their mathematics courses.

Student-artists came together for a series of four approximately one-hour sessions of individual and collective arts creation and reflection on their curricular experiences, with an emphasis on their interpretations of the (in)coherence of cross-curricular mathematical stories. I started by asking about their definitions of (in)coherence, beginning in familiar, everyday contexts ("a story, a TV show, or movie, a song, a conversation, etc.") and ending with the cross-curricular mathematical context. Next, students created artwork to reflect on the coherences or incoherences they had noticed or felt across their undergraduate mathematics courses. Following an arts-based research approach (Leavy, 2018), participants created and then discussed art in the form of their choosing to allow for a holistic, multimodal, and multisensory investigation of the learned mathematics curriculum (Bagnoli, 2009; Papoi, 2017). This centered opportunities for reflection on the roles that *aesthetic* as well as logical forces played in making curricular stories connect and cohere (Clark & Rossiter, 2008; Sinclair, 2009) across their everyday mathematical experiences. It also enabled student-artists to depict both positive and negative emotions related to these experiences. To allow for cross-pollination of perspectives (Leavy, 2020) on curricular coherence across artists and their artwork, private exhibitions of their art were used to elicit

richer group conversation and subsequent mathematical storytelling about their interpretations and feelings concerning the (in)coherence of their cross-curricular experiences. Interactions were spread over a period spanning three months to allow sustained space for artists to consider alternative perspectives and (co-)develop more nuanced critiques of their curricular experiences.

In line with most arts-based research, analysis went beyond reducing artwork, curricular critique, and complex discussion into a list of collectively agreed upon themes (i.e., a *similarity* analysis) (MacLure, 2006, 2013). As McNiff (2018) put it, "Of course, themes exist in life and art, but there are many other things too—characteristics, features, aspects, principles, ideas, patterns, structures, designs, compositions, similarities and differences" (pp. 29–30). In particular, analysis was conducted in two flanks: (a) a *participatory analyses* conducted by student artists across both group discussions based on each other's artwork and (2) a *collage analysis* (Butler-Kisber, 2008; Scotti & Chilton, 2018) that I used to juxtapose students' metaphors for curricular coherence with those found in the literature. Specifically, by cutting out ephemera from students' curricular critiques (i.e., visuals from photocopies of their art and transcripts from our individual and group conversations), I was able to *live and breathe* students' perspectives on coherence to further empathize with and understand the nuances of these perspectives (Margolin, 2014). I purposefully omit an image of the collage because my aim is to spotlight *students'* interpretations of curricular coherence (rather than my own). However, further methodological details and the collage can be found in Tyburski (2024).

Learning From Student Artwork

Student-artists regularly acknowledged how judgements of coherence are idiosyncratic and subjective. Fred, for example, explained how his experiences across mathematics courses felt "flowy" and coherent, but then quickly added the caveat that "Some people kind of struggle with math and, yeah, we all have our own strengths and weaknesses. I'm not really a good essay writer, so that is probably coherent to someone and that's not coherent to me". As VKN put it, "a lot of people don't experience math the same way I do . . . there are different lenses and different levels of coherence". Comments such as these foreshadowed *several* interpretations of curricular coherence that deviated from disciplinary, logico-rational forms of coherence.

Among these, I focus herein on different *emotional* forms of coherence students proposed. For example, wuyen shared that emotional investment played a leading role in interpreting whether a story (mathematical or otherwise) was coherent to her. For a story to make sense to her, it had to make her feel: "I think emotional [*sic*] is a big component for me to make things make sense because I'm a very emotionally driven person, more than logic for sure" In particular, she found Taylor Swift's discography to be coherent because of the emotional stories told in each of her songs and albums. She also expressed a similar view of mathematical coherence when I introduced the curriculum-as-story metaphor late in our first group discussion:

> The different applications of math as a story was [*sic*] very interesting because to me during our first conversation, we were talking about how stories make sense to me if it was emotionally touching in some way to me. So, applying that to the bigger idea now of the whole math experience being a story, I feel like emotions still should play a part.
>
> Well, not *should*. For me, it *does* play a part in the math journey to make it make sense.

wuyen expressed a clear aesthetic preference for stories that involved emotion and made her feel. For her, *these* stories were coherent. Meanwhile, Fred likened his love for math to his love of Disney animated movies, concluding that "I'd say math is kind of similar, *if* you care about math. I kind of care a little too much about math. Other people don't give a shit about it". In both

these cases, wuyen and Fred alluded to the inseparable relationship between aesthetic sensibilities, emotion, and preferences for particular kinds of (curricular) stories.

Emotions were not just peripheral for these student-artists: they played a leading role in their holistic aesthetic judgements of the (in)coherence of cross-curricular mathematical stories. VKN, for instance, regularly brought up a negative experience she had with unit vectors in multivariable calculus across our interactions: "I passed multivariable calculus. Got a 4.0 even. I 'understood' it. And yet, I am sitting here trying to remember what the hell unit vectors are". When I asked VKN follow-up questions, I was surprised to learn that (at least from my perspective) she understood the normative definition and uses of a unit vector, at least the recurring ones privileged most by the traditional multivariable calculus (MVC) curriculum. Rather, she was hung up primarily on how a particular unit vector was used in just *one* formula that *did not* recur throughout the MVC curriculum. From the perspective of a disciplinary expert, I perceived this formula to be largely insignificant to the overarching story of MVC, yet this local experience of extreme *emotional* incoherence colored her entire perception of the MVC curriculum as *in*coherent. This was not an isolated case: Joy similarly reflected about how she perceived her cross-curricular mathematical experiences to be largely *incoherent* for the years it took her to feel comfortable with logarithms. Just like when reading any literary story, *emotional* factors were the deciding factor between whether a cross-curricular mathematical story was enjoyable and coherent or confusing and incoherent for multiple student-artists.

Figure 1. Joy's The Smoke Trail

Joy's *The Smoke Trail* (Figure 1) is one of most evocative pieces in terms of conveying the central role that emotion played in some students' judgements about mathematical (in)coherence. In her art, Joy reflected on how she frequently *saw* the seemingly coherent "fire" of the mathematics curriculum but would often struggle to reach this fire in practice (i.e., to interpret her mathematics experiences as fully coherent), even when she had a smoke trail leading her to it. The deceptiveness of the smoke trail and how it "would come into [Joy's] lungs and choke [her] out as opposed to gently guiding [her] along" (as expressed in her artist statement) were part of why her entire painting takes place next to a frozen lake. As she shared, "I started with the color blue because that's how [mathematics] made me feel. . . . isolated. Sad." The frozen-over blue lake that dominates the foreground of Joy's art emphasizes that judgements of mathematical coherence for her are governed by a looming sense of sadness, as well as other emotionally painful memories that she likened to being choked, drowned, or burned alive. For Joy, mathematical coherence seeking was often panic-inducing and marked by negative emotion.

Discussion and Conclusion

In light of these student perspectives on curricular (in)coherence that deviate from logico-rational forms of curricular coherence, the epistemic harm (Tanswell & Rittberg, 2020) of privileging just one strict view of coherence becomes apparent. For starters, adherence to just one curricular aesthetics of coherence fails to capture the aesthetic and affective idiosyncrasies students attended to as they engaged in their coherence seeking processes. Worse, a devotion to just one set of aesthetic values can enforce an exclusionary politics of aesthetics that conveys messages about who/what is (in)coherent (Appelbaum, 2010; Buchmann & Floden, 1991). This phenomenon was on full display across Joy, wuyen's, and VKN's curricular reflections and critiques, where they often positioned themselves as struggling or incapable as they strove to interpret the cross-curricular mathematical stories they had engaged with as coherent. Recall, for example, Joy's hauntingly evocative art in which she recounted how seeking disciplinary coherence across her mathematics courses has led to her repeatedly feel as if she was being choked or even burned alive by the *supposedly* ideal "fire" of (disciplinary) coherence.

All three of these participants were highly successful mathematics students in the grand scheme of the K-16 mathematics curriculum that had successfully completed most of the undergraduate calculus sequence and all preceding pre-requisite courses. Still, I listened repeatedly as they expressed perpetual frustration about "not seeing" the (disciplinary) curricular coherence across mathematical stories expressed in other students' artwork. Though each of these students eloquently expressed highly idiosyncratic perspectives on curricular (in)coherence that deviated from disciplinary coherence, they appeared to have internalized that disciplinary forms of coherence were "more desirable" and "more correct" than their own. It was not until the final group discussion that each of these students started to challenge these deficit views they held about their own aesthetic judgements. This appeared to be a positive and perhaps even empowering outcome for these participants. But what about the other students navigating these exclusionary politics of mathematical aesthetics without sufficient space for critical reflection?

While the culture of exclusion (Louie, 2017) in mathematics classrooms is not something that will be solved overnight with just one change, there are some concrete steps that can be taken to mitigate these harms in future curricular coherence research. We can remain open to *several* perspectives on curricular (in)coherence, rather than strictly espousing just one perspective. This can be done by explicitly acknowledging the fundamentally *aesthetic* nature of making judgements about curricular coherence, clarifying that coherence seeking is *not* an objective evaluation but an idiosyncratic judgement based on one's personal aesthetic sensibilities. In other words, not everyone will find the same curricular story to be "coherent". While the definition of "coherence seeking" offered by Sikorski and Hammer (2017) does much to shift power into the hands of students to make their own judgements about what is coherent, it still positions this activity as a mostly *cognitive* act. Almost nothing is said about the *emotional* and *aesthetic* factors that influence coherence seeking (as demonstrated across students' perspectives in this study). Future research, therefore, ought to more explicitly embrace (as well as further investigate) how affective forces and other value judgements (including *aesthetics*) influence and *drive* coherence seeking. As past research in mathematics education repeatedly demonstrates, such aesthetic forces play a highly non-trivial but often overlooked role in students' mathematical activities (e.g., Fiori & Selling, 2016; Jasien & Horn, 2022). It is high time that we fully acknowledge how these personal subjectivities impact judgements of mathematical coherence and, in doing so, begin to rid our discipline of the dangerous myth that mathematics is objective, pure, or immune to exclusionary politics of aesthetics.

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